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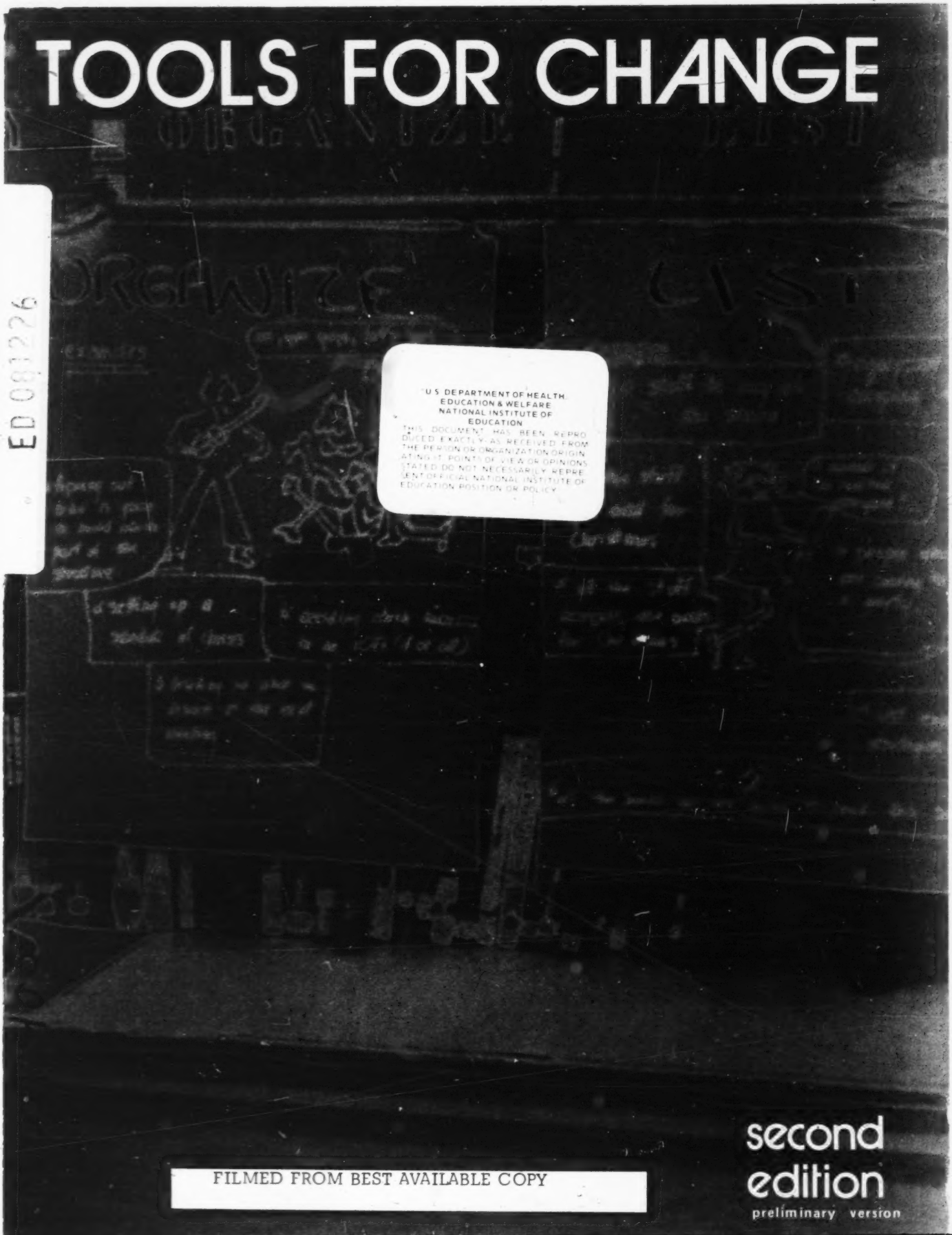
ABSTRACT

An introduction for teachers to Tools for Change, a new course in problem-solving, is provided by this sourcebook. The major assumptions and rationale underlying the course are explained and the most significant concepts involved--such as heuristics and problem-solving--are scrutinized. Examples of problems and process-oriented problem-solving are given and serve as an introduction to a discussion of how to teach problem-solving, connect it with other academic subjects, assess student needs, and motivate pupils. The importance of the process approach to the world at large, to teacher education, and to schools in general is briefly examined. A glossary of heuristic terms and a short bibliography are also included. (For related documents, see EM 011 404, 406.) (PB)

TOOLS FOR CHANGE



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goals

Interaction Associates, Inc., researches, develops and applies conceptual and technological tools for problem-solving. We are interested in how man solves problems as an individual and in groups, how he teaches others what he knows, and how he augments his ability to solve problems with the use of technology. Our expertise is in process, and our goal is to become a resource for others in need of tools.

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tools for change

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acknowledgements

Tools for Change originated with the work of David Straus. Portions of this book appeared in an earlier form in his 'Problem Solving Notebook.' The first edition of **Tools for Change** was written by David in conjunction with Chris and Ruth Thorsen. Ethan Gluck was the fourth member of the team that accomplished the first year of work.

This book, written to introduce teachers to Tools for Change, was shaped by the Tools for Change staff: Barbara Abrahams, Sharon Anderson, Pat Crowley, Bill Curran, Ron Jones, Jim Kerr, Catherine McEver, Mary Sawyer, Cary Sneider, Diane Streeter, Rudie Tretten, Flew Waidner, Linda Williams, Jim Winder, and Jackie Yokote. Editor, Lucinda L. Kindred, assisted by Marg Donnelly, David Straus, and Penelope Wong-Berner. Graphics and layout by Tom Glass, Pictures and Words, San Francisco. Production by Penelope Wong-Berner and Richie Gordon.

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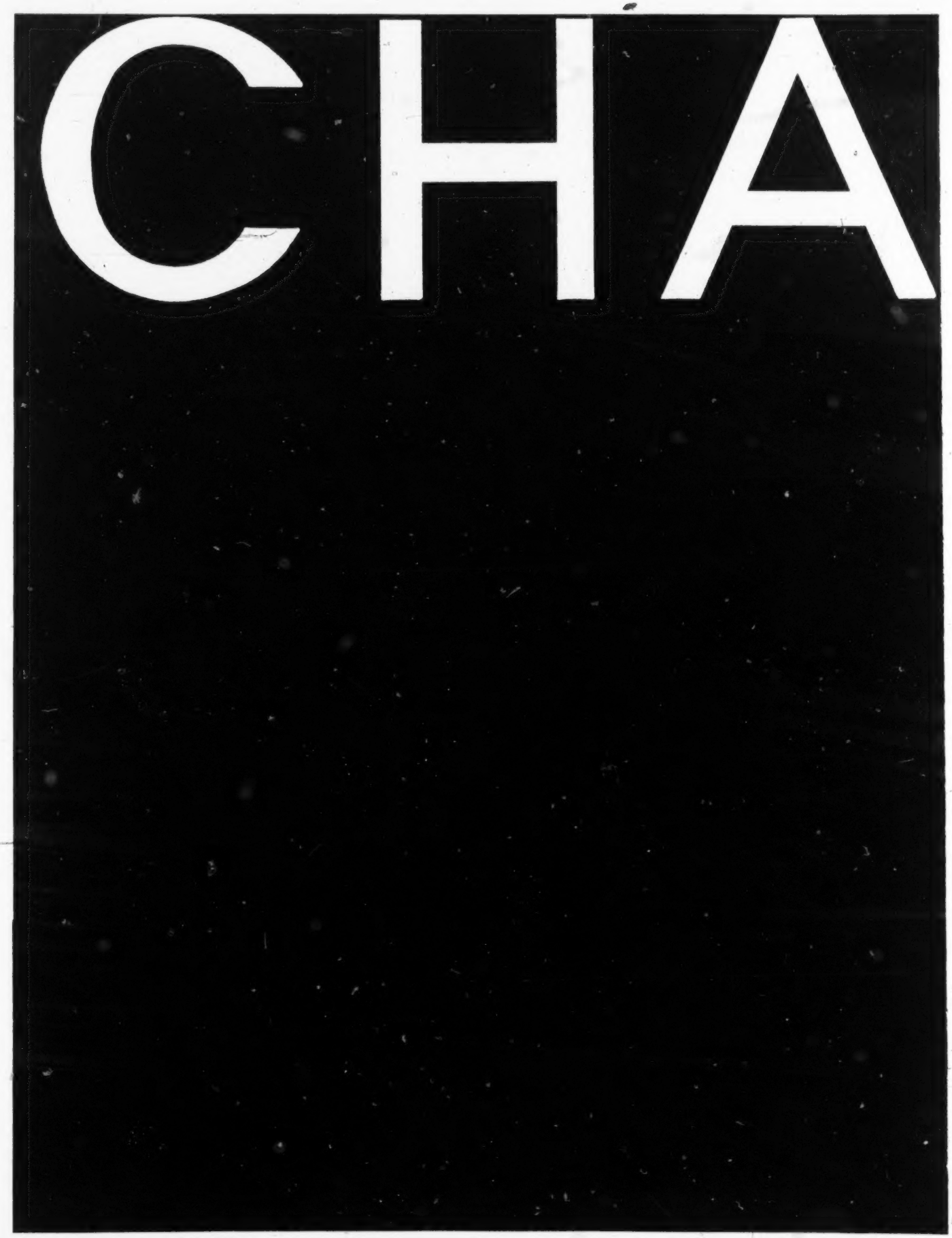
n.b.

This is a preliminary edition of a work in progress. It is a pulling together of existing fragments without a major rewrite. However, we thought it would be useful to present it in this form before further revision. It has major inconsistencies, but should be viewed as a teacher sourcebook in Tools for Change.

We invite your feedback on its content and usefulness. Enclosed is a 'feedback format' that we would like you to complete and return.

introduction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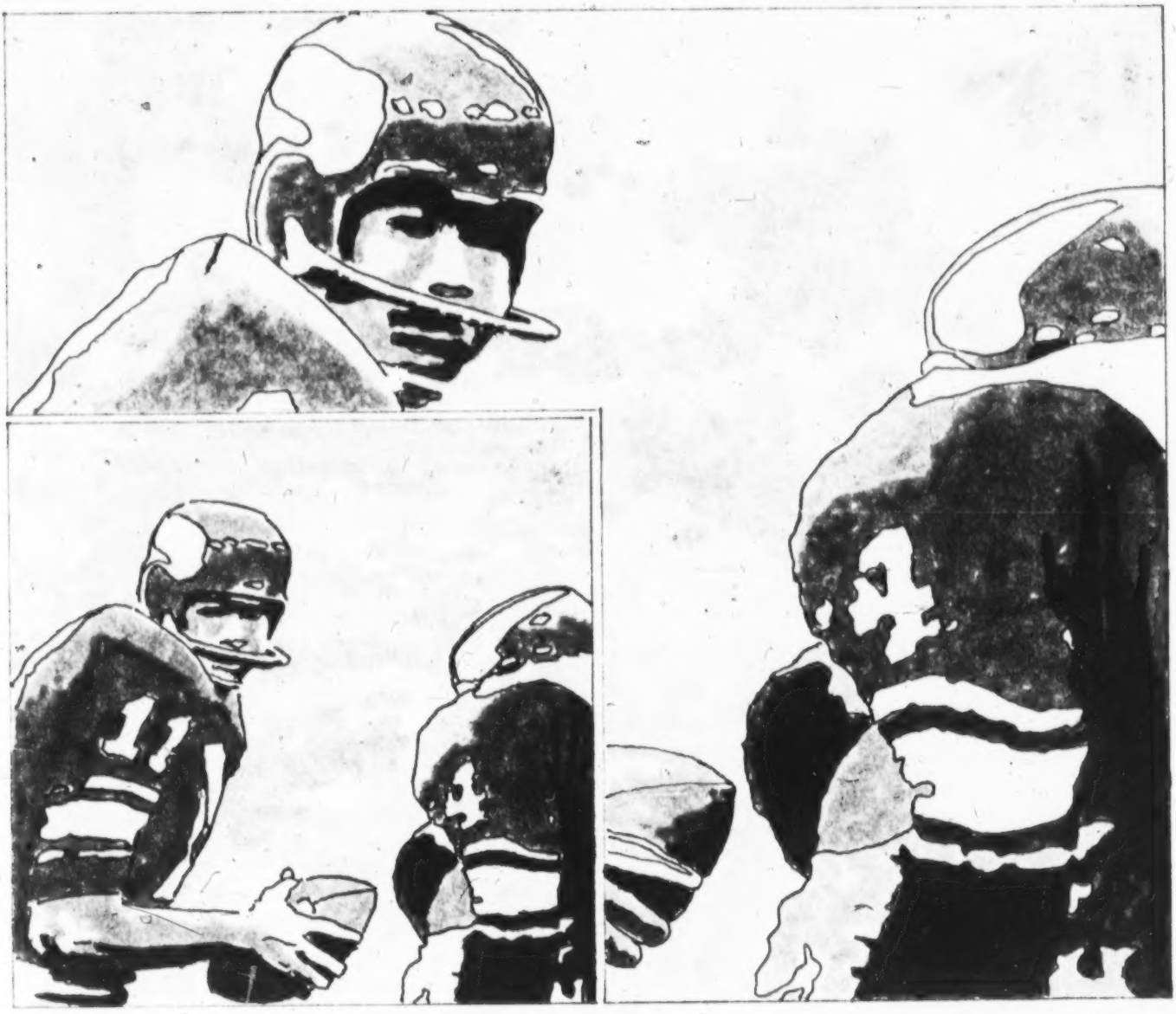
...values, technology, attitudes--the world is changing at an ever-increasing rate. How do we prepare ourselves for a world of change? What can we offer children that will be useful in a future we cannot predict? Can we provide them with some tools for change?

What should these tools be? Traditional technical tools are not enough. Science and technology are changing too fast. What is new now will be obsolete in ten years. Concepts and facts are not enough either; they change as our perceptions change. Effective tools must be able to live through change. They should deal with **how**, not **what**. The most effective tools are **processes**, actions or series of actions that produce change and that are independent of particular situations but apply to many.

It is a basic thesis of **Tools for Change** that these ongoing processes can be identified. They can be taught and learned. Furthermore, the resulting vocabulary is useful in assisting humans to learn and change. These tools may be one of the few things of lasting value in the educational experience. The purpose of this book is to introduce teachers to these 'tools for change' as a new approach to teaching and learning.

The tools, or processes, are simply actions or series of actions that produce change. Once we are aware that such processes exist, we can identify the particular processes that we use in everyday living. Then we can focus on specific techniques that will increase the usefulness of our existing processes and learn new ones.

While processes are important in bringing about change, actions alone are not enough. We must be able to react to these actions—to evaluate and then adjust to a particular success or failure. Life is a series of adjustments: action, reaction, adjustment, and then action again.



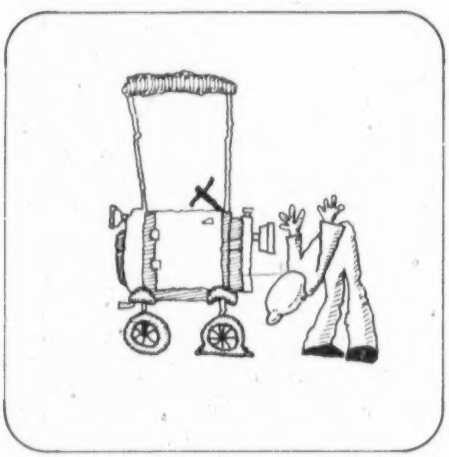
we make a move, instantly evaluate the effect of our action, and adjust our next action accordingly

Engineers call this process 'feedback.' Life can be seen as a constant trial-and-error procedure. Trial—because we are never sure that our actions will be successful; error—because our trials rarely produce exactly the change we expect, so we make another trial.

That's where heuristic processes come in. The heuristic process (also called heuristic strategy or just plain heuristic) is a trial-and-error approach to dealing with a situation. It relies on feedback from different processes before taking the next action. **Tools for Change** has organized these processes, specifically those involved in problem-solving, into general sets that can be of value as tools for dealing with the problems of the future.

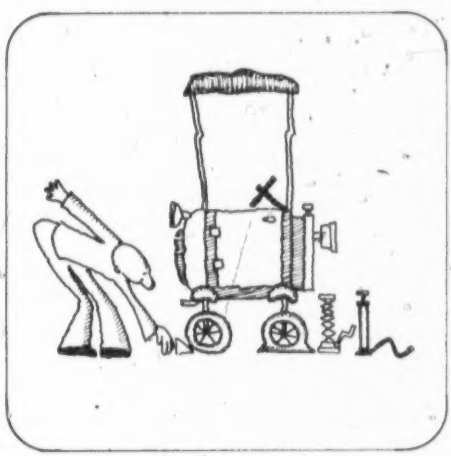
we define a problem as a situation someone perceives as having to be changed: a conflict between what exists, and what should be. problem-solving, therefore, is situation-changing or conflict-resolving.

in its most general sense, problem-solving



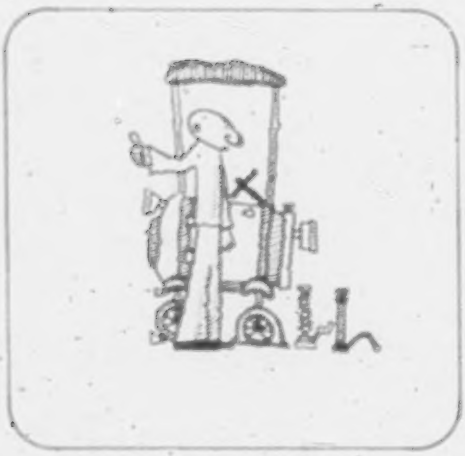
analyzing,

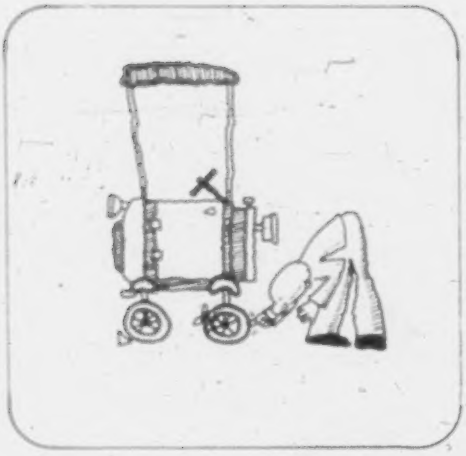
remembering,

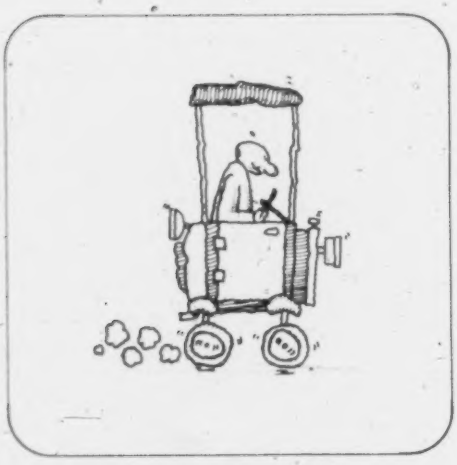


planning,

includes the actions involved in: perceiving,



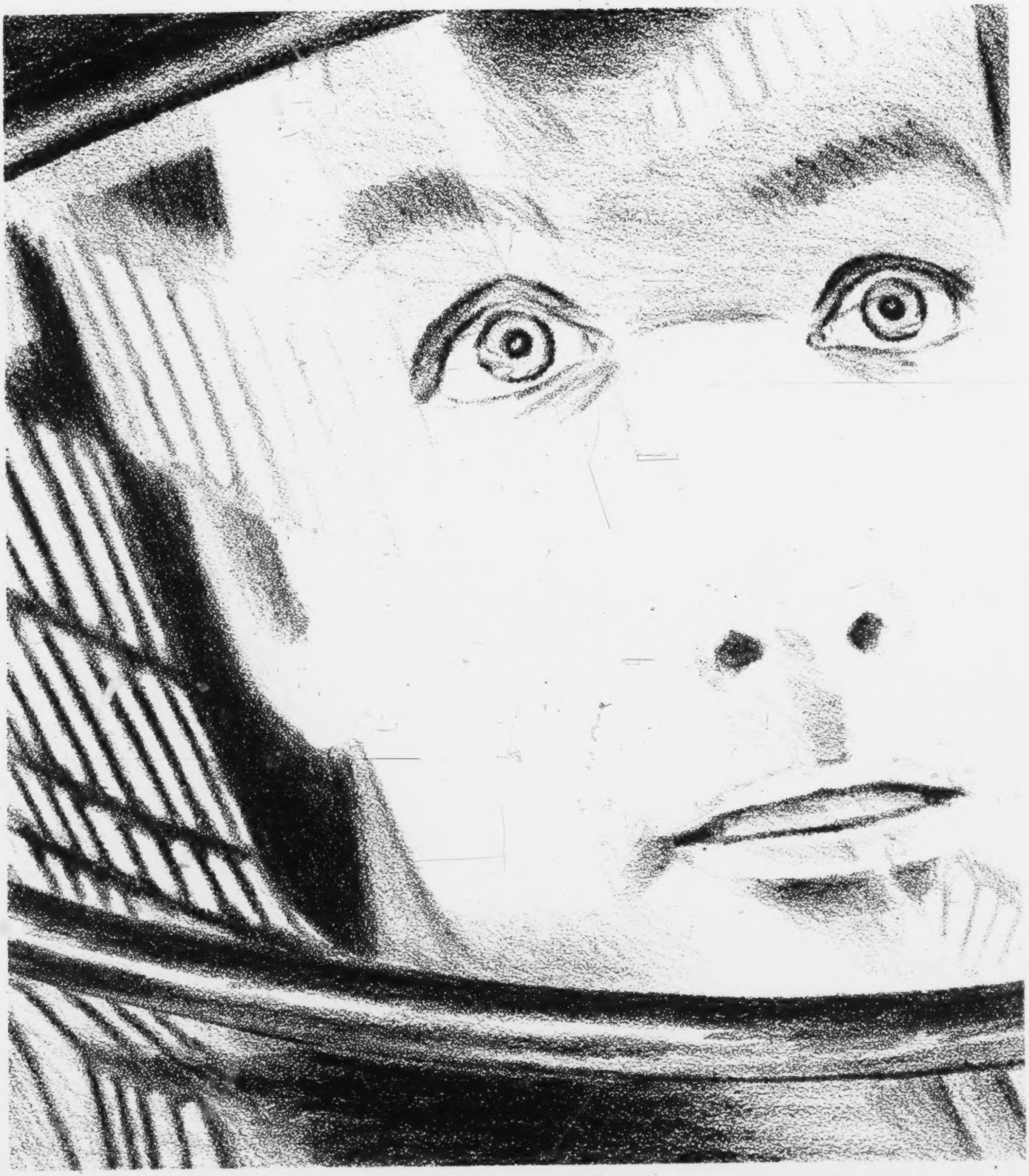




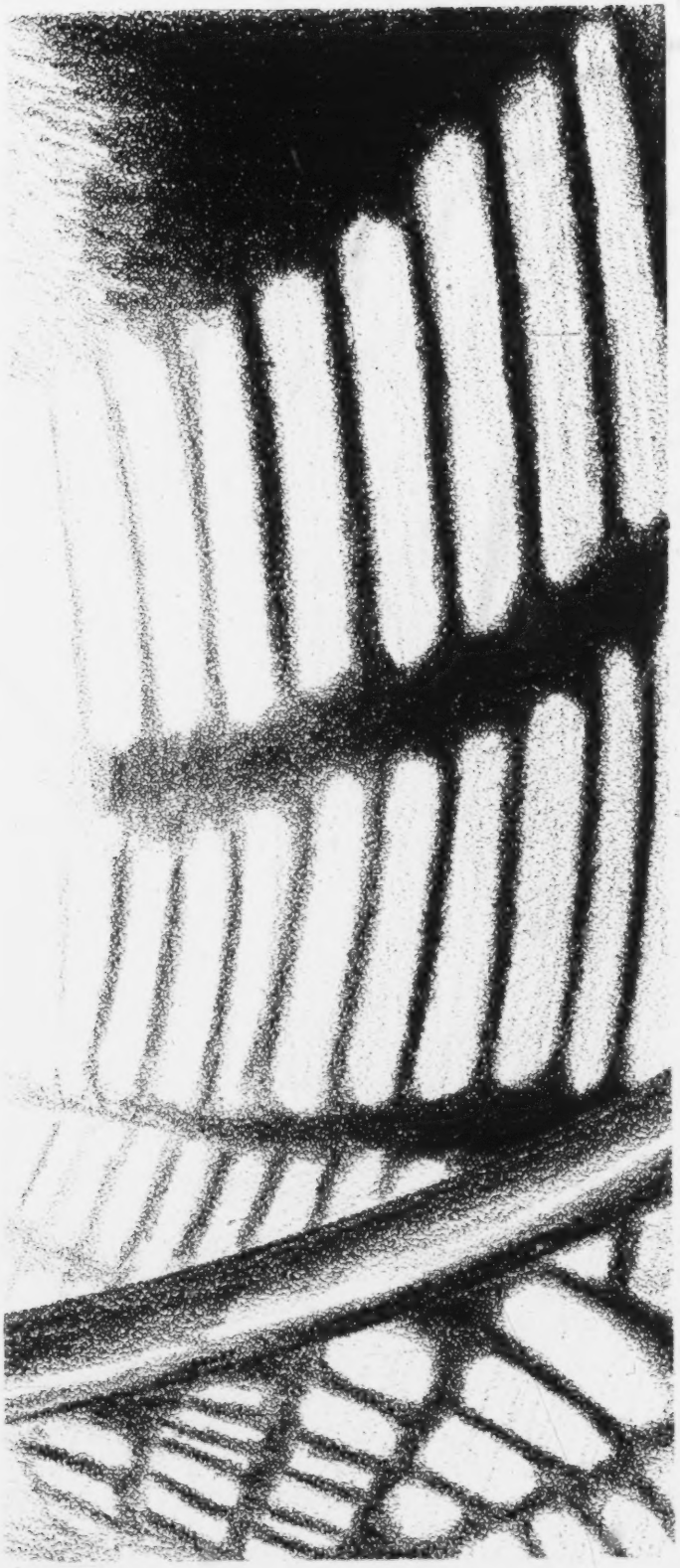
alternative generating, evaluating, and synthesizing.

We are successful problem-solvers inasmuch as we are able to intelligently select a heuristic process to meet each new situation. Obviously, most of us are reasonably good problem-solvers, or else we would not be alive. Most of our trial-and-error living is based on subconscious patterns gradually formulated to deal with problems we meet over and over. **Tools for Change** aims to make us conscious of these patterns and, as a result, to help us become better problem-solvers.

but what happens when we meet a

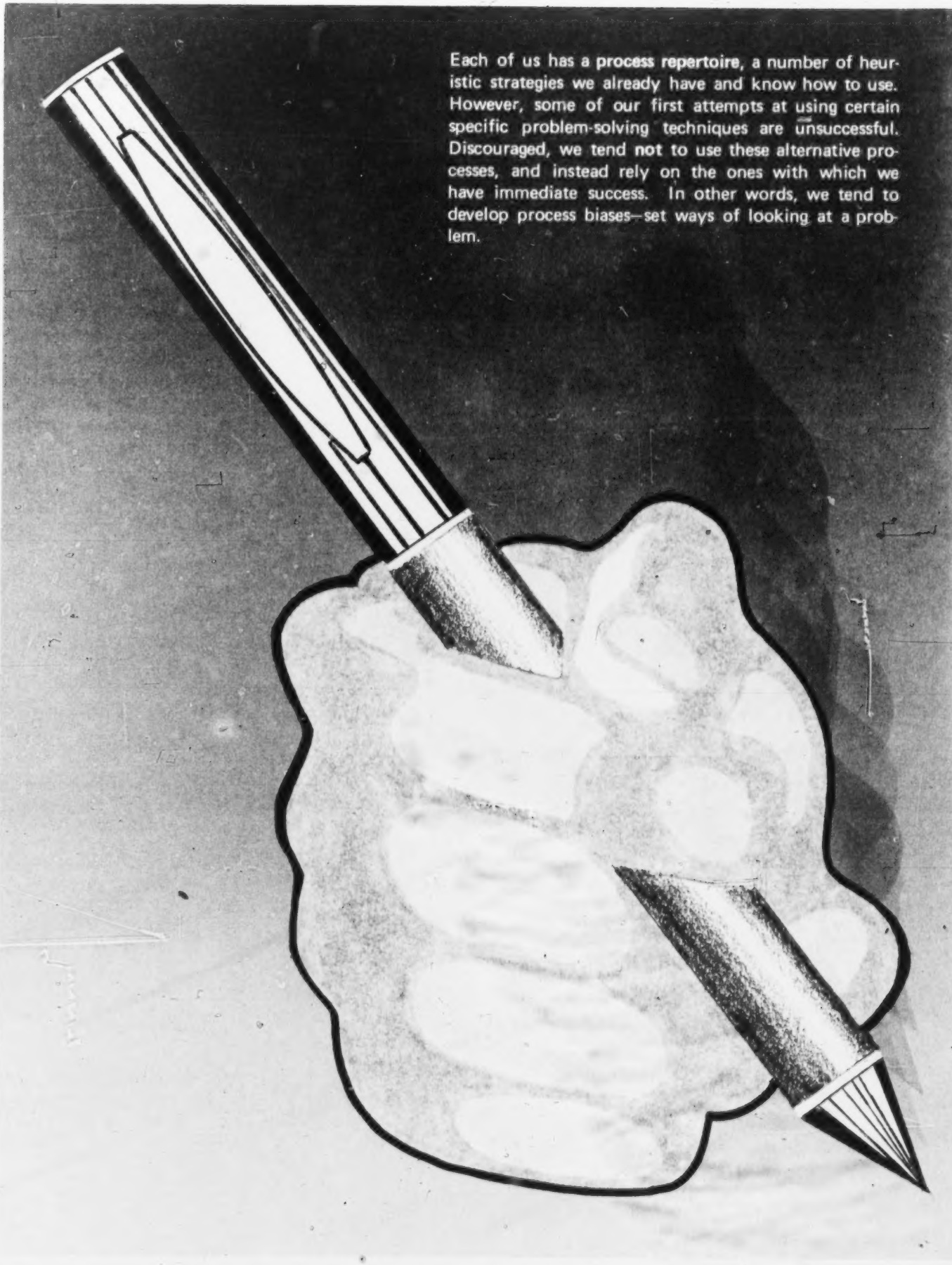


)roblem we have never seen before?

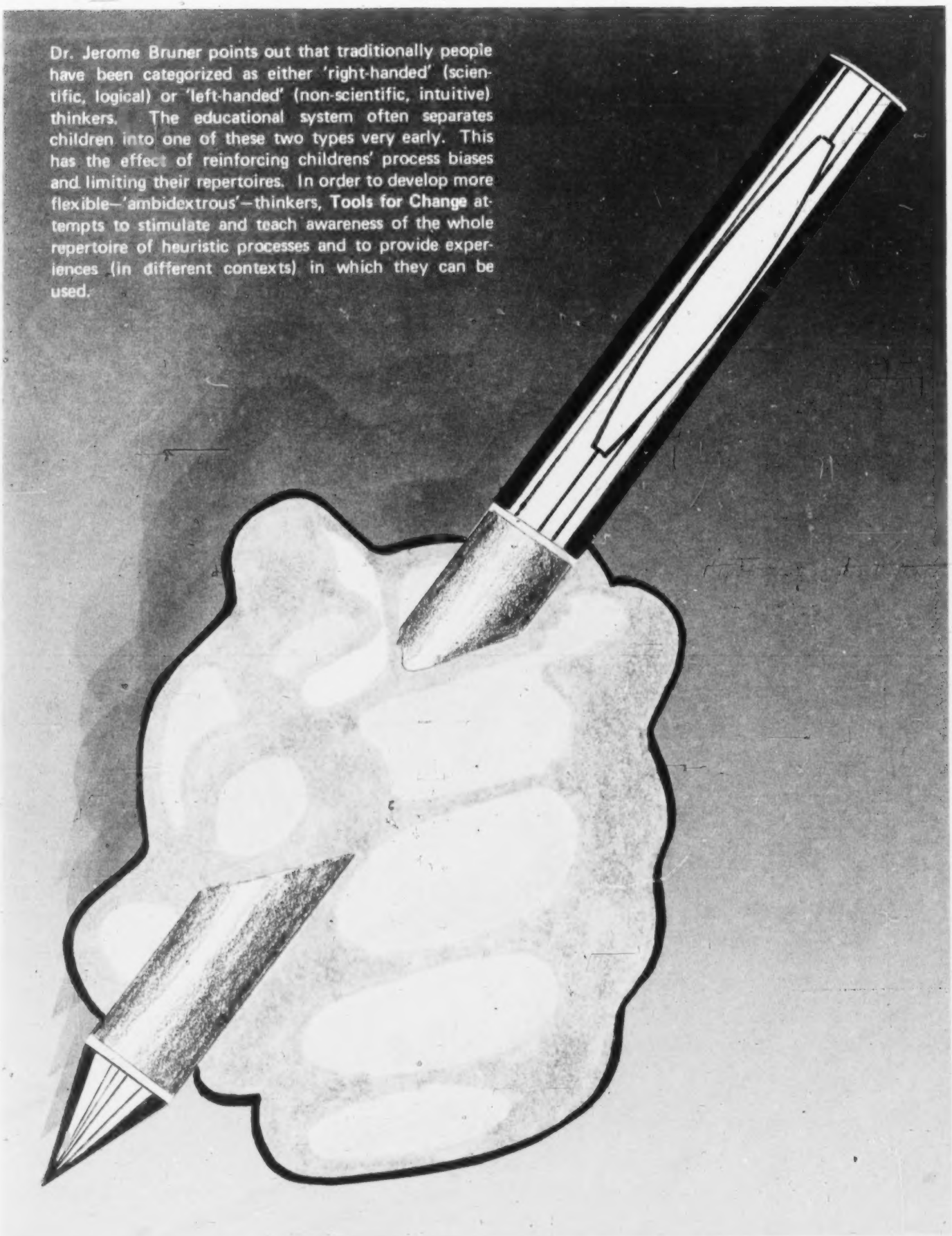


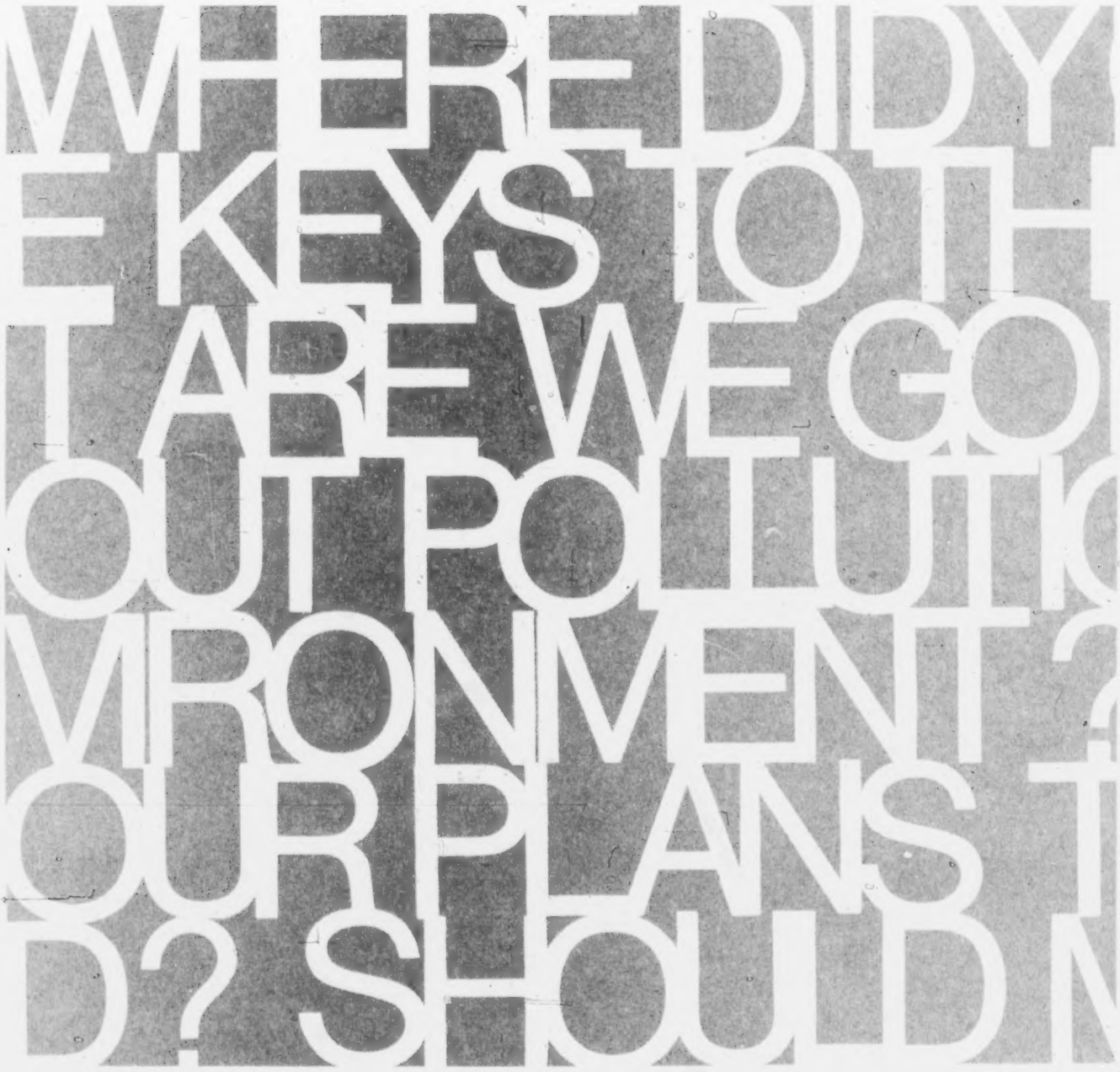
Habitual responses are not always satisfactory. A new problem may require a new response or tool. When we become aware of the availability of alternative tools, we are more likely to use appropriate ones.

A good problem-solver is like a good carpenter. The carpenter has an array of tools available to him. He knows the powers and limitations of each. When he encounters a new problem, he can look over his repertoire of tools and make an intelligent choice as to which ones are most likely to do the job. A good problem solver also has his repertoire of tools. When a new problem arises, he can select the most appropriate heuristic as his tool to respond to the problem.



Each of us has a **process repertoire**, a number of heuristic strategies we already have and know how to use. However, some of our first attempts at using certain specific problem-solving techniques are unsuccessful. Discouraged, we tend **not** to use these alternative processes, and instead rely on the ones with which we have immediate success. In other words, we tend to develop process biases—set ways of looking at a problem.

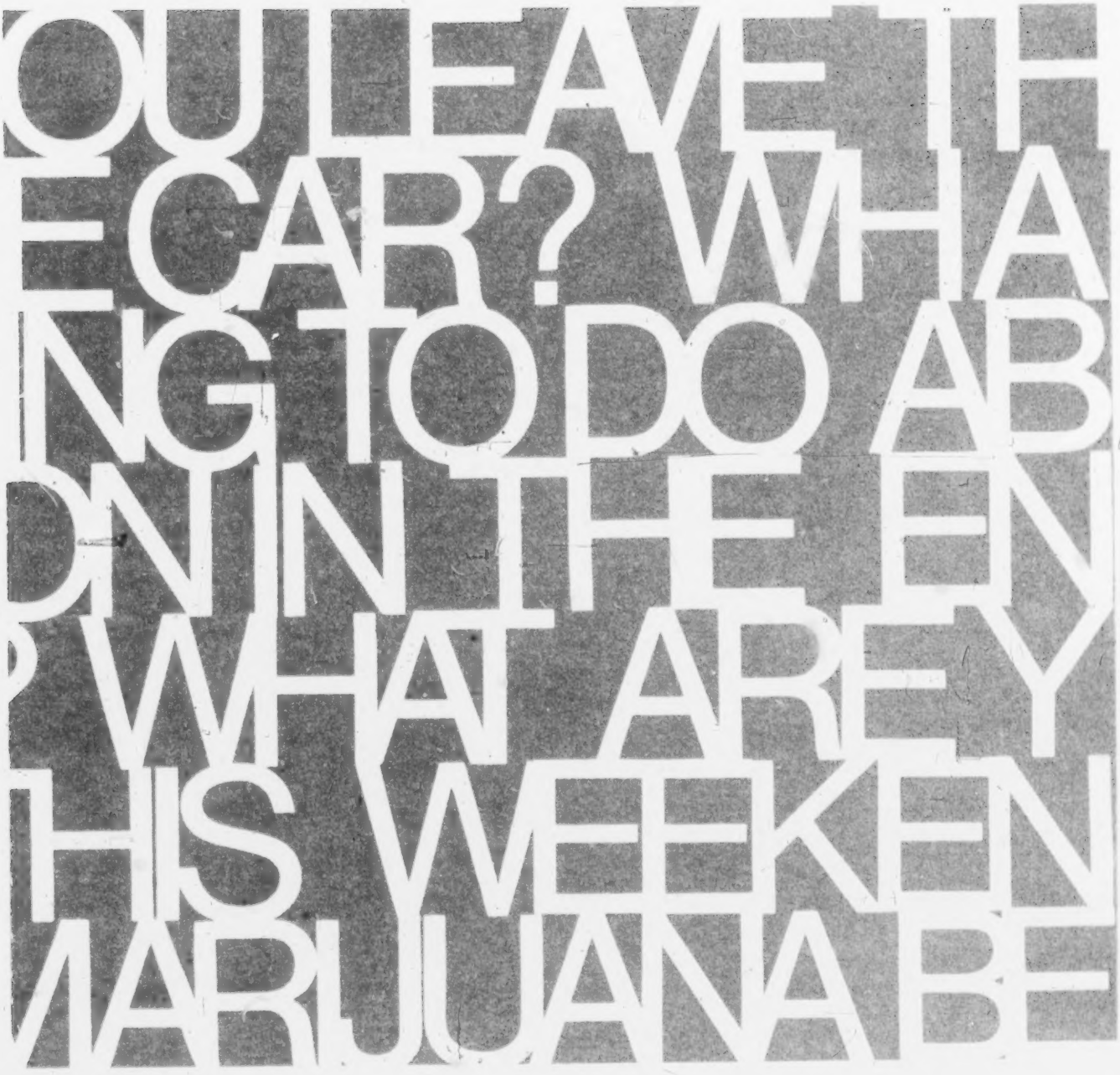

Dr. Jerome Bruner points out that traditionally people have been categorized as either 'right-handed' (scientific, logical) or 'left-handed' (non-scientific, intuitive) thinkers. The educational system often separates children into one of these two types very early. This has the effect of reinforcing childrens' process biases and limiting their repertoires. In order to develop more flexible—'ambidextrous'—thinkers, **Tools for Change** attempts to stimulate and teach awareness of the whole repertoire of heuristic processes and to provide experiences (in different contexts) in which they can be used.



problem-solving

All of these are problems. Some can be handled easily, some cannot. In our lives, we all encounter problems of perception, searching, remembering, planning, and designing, to mention a few. How do we go about solving problems? Here is a summary of what has been learned about problem-solving in recent years, translated into simple processes that can be helpful to you, the problem-solver.

It is not enough to just talk about problem-solving: to understand it, you have to actually experience the process. You are going to need real problems to refer to. Take a look at those on the next few pages.



While you are working the problems, be aware of what you are doing. One way to become aware of your problem-solving process is to keep a record. In the space provided, list exactly what you are doing through each of the examples.

These problems are called anagrams. They are scrambled letters that spell some word. Though they are very simple, they are often frustrating. Take a few minutes. Problem-solving is work, and there is nothing in this book that will change that. Once you have actively struggled with the problems, you will be better equipped for the discussion of problem-solving which follows.

some anagram problems

Each of these combinations of letters spells a word (sometimes several). Work on one at a time. Read the discussion on the next page after completing each problem.

lae	laer	laery	tbalaery

discussion of anagram problems

lae

This one probably only took you a few seconds to work out. You looked at the three letters for a moment, shuffled them around, and quickly found the answer.

laer

Probably didn't take much longer. You could still do it in your head. Did you find more than one 'right' answer?

laery

Perhaps this one took a little longer. You may have been more conscious of shuffling through the various combinations of the letters in your head, or you may have used the blank paper. You probably tried a few unpronounceable combinations before you got it. In fact, in this case, there are several 'right' answers.

tbalaery

Even more difficult? Struggle with it for a while, and keep a written record of what you are doing. First of all, it should be obvious that you couldn't just look at the letters and have the solution pop into your head. Even for this rather simple problem of eight variables, it would be almost impossible to test all the combinations of the letters in your head. In fact, there are 20,160 possible combinations: if you could test one combination every second, it could still take nearly 56 continuous hours of testing before you had worked through the complete set—that is, if you could remember and keep straight in your head which ones you had already tried. And, obviously, if you worked on paper, systematically proceeding through all of the possible combinations, the procedure would be prohibitively time-consuming.

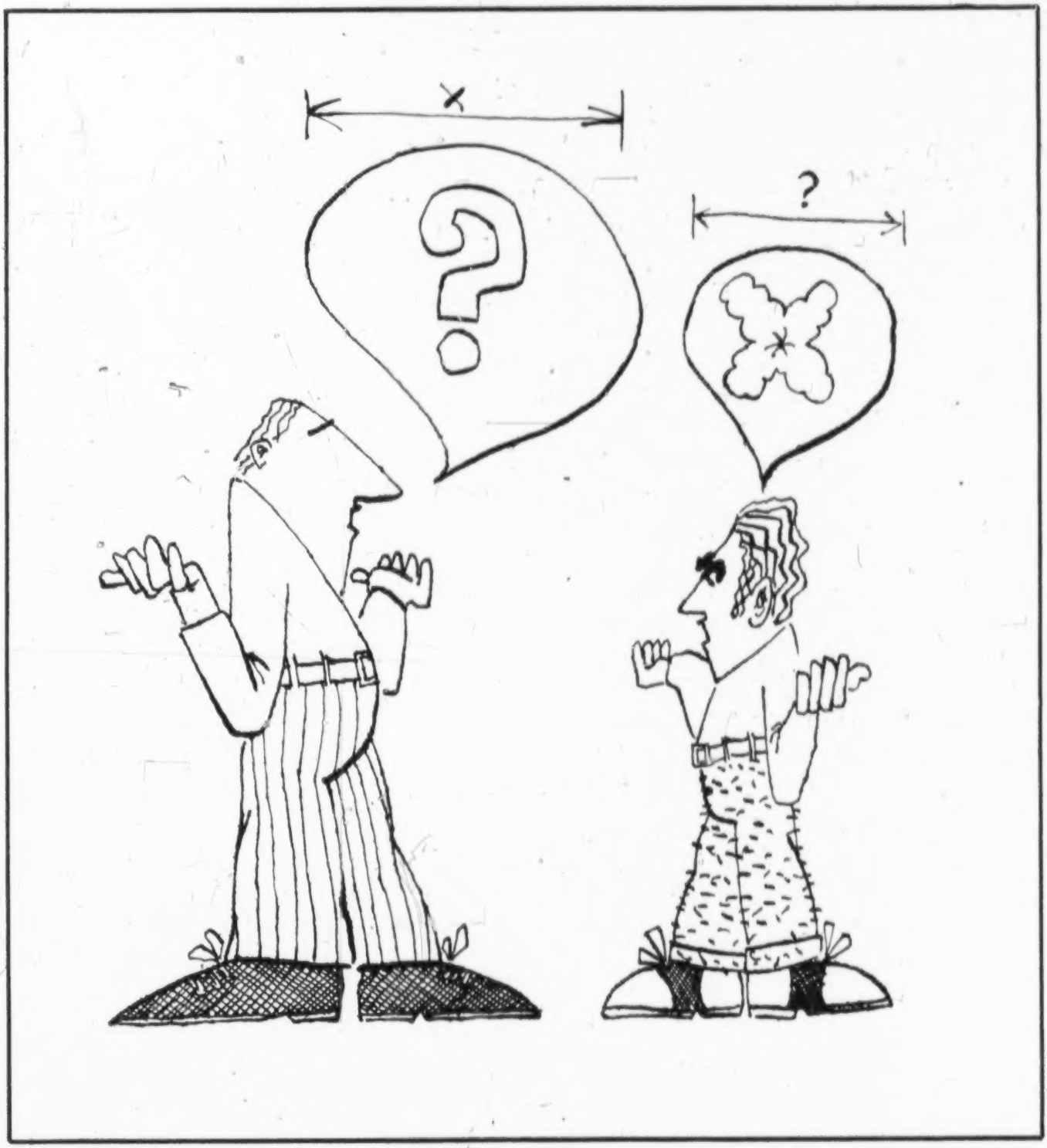
The point is that even for this simple, well-defined problem with one right answer, for reason of the length of time involved in being completely systematic, you are forced to try to reduce the scope of the problem, and to try something else. For instance, you might begin by ordering the letters alphabetically, grouping them by vowels and consonants: AAEYBLRT. Then you might try to examine this ordering for any basic implications. For example, you notice that there are four vowels to four consonants, so the word could have vowel-consonant alteration throughout, or else two vowels must appear together. What vowel combinations are possible? AE, EA, EAY, AY and maybe YE and YA. Take EA, that would leave an A and Y either together or alone. Y likes to come at the end of a word, so maybe you might have ARY. So that would leave EA and ARY. You could then try to fit in the consonants. Or you could play with different phonetic combinations and avoid all unpronounceable combinations like TBL. Or, if you are experienced with anagrams, you might have worked out what are the most common combinations of letters and started with those.

These different lines of reasoning or approaches that you used to cope with the anagram problems are called 'strategies.' There are many different strategies that you could have applied to try to reduce the problem to manageable size. The characteristic of each of these strategies is that it makes a try in one direction. It does not guarantee success: it could help, but then again it might not. You are never really sure. A strategy takes you away from neutral ground towards one corner of the problem. And for each direction that you can go, there is probably at least one opposite direction that might be equally helpful. The fact is that you have to move mentally; you cannot just stand in one place and blink your eyes and hope that the solution will appear. You have to commit yourself in some direction for a period of time. And there are successful commitments and unsuccessful ones.

Are you aware of how you are committing yourself when you tackle a problem? Are you aware of the other approaches that might be helpful to you? Have you ever stopped to look at the potential inventory of strategies that are available to you? Do you know the inherent powers and limitations of each?

definitions

We have very few words to describe thought process. Therefore, most of us are not very conscious of the basic patterns in our thinking and have few commonly accepted words to talk about them. That is why we need some basic definitions.



problem: a problem is a situation that somebody wants to change.

A problem is only a problem in relation to someone. A situation you perceive as a problem may not be so for someone else. Moreover, you must recognize the situation as a 'problem' for it to exist as such. You may see your children fighting. If they are having fun and you are not worried about it, then there is no real conflict or problem for you. (It may, however, be a problem for them.) If you are worried about their fighting but do not want to do anything about it, then the problem is only a description of a state of conflict. It is a **descriptive problem**, in that you recognize a state of conflict but wish to play a passive part in it.

For a problem to become an active, **meaningful problem**, you must want to act and do something about it, to change it in some way. If you simply looked at the anagram question and assumed that you could never solve it, then it was just a descriptive problem for you. If you really rolled up your sleeves and took a crack at it, then it became a meaningful problem. In other words, there must be both a problem and a problem-solver to have the conditions of a meaningful problem.

There are three basic types of problems. **Trivial problems** are problems that you can solve by an immediate and often subconscious response. Some examples include ducking when something is thrown at you, shading your eyes from bright light, walking around an obstacle.

Secondly, there are **well-defined, closed problems.** Problems of this kind are easy to recognize and understand, and have a limited number of correct solutions. A search problem, like the anagram problem you tried, is an example of a well-defined problem with a limited number of solutions. Looking for your socks in the morning or searching for a piece of information are other examples. You know what you are looking for, and you know when you have found it. Many of the problems we daily face are of this type.

Finally, there are **ill-defined, open-ended problems.** In these it is not clear what the real conflict is, nor is there only one right answer. Writing a term paper in school, designing a building, choosing a mate—these are all open-ended problems, and you can never be absolutely sure you have come up with the best answer. The most difficult and important problems we face are of this type. And, of course, there are many different gradations and combinations of these problem types: well-defined and open-ended, ill-defined and closed, etc.

solution: a problem is solved when the situation has been changed satisfactorily.

Because it has a connotation of the clarity and finality involved in mathematical problem-solving, 'solve' is an unfortunate word to use here. The word 'resolve' would be more precise, but for ease of communication and because this whole subject has become known as 'problem-**solving**,' the word 'solve' will be used. An important thing to remember is that solving is really reducing the state of conflict, or changing the situation satisfactorily.

process

An action (or series of actions) that produces change. A process is the movement or transition between situations or states as opposed to situations themselves. The word 'process' has become a much overused and all-inclusive term. Therefore, we find it useful to define 'process' at three different levels of abstraction: **method, strategy,** and **operation.**

method

A method is an ordered sequence of strategies useful for solving certain kinds of problems. For example, 'brainstorming,' a well known method of generating new ideas, can be described as a sequence of strategies: 'purge' any idea that comes into mind, 'list' all suggestions and 'defer' evaluation. While we feel it is useful to know about certain basic methods, it is more important that the individual learn how to design his own methods out of the basic set of strategies.

strategy

A strategy is a **conceptual approach** to making change and solving problems. In our terms the concept inherent in a strategy is independent of context. In other words, a strategy should be able to be used in almost all kinds of problems. A strategy can be thought of as a command that you can give yourself or somebody else working on a problem that is not so general as to be meaningless ('work hard,' 'think hard,' 'don't be stupid'), and not so specific as to be only useful for very specific kinds of problems ('open with a pawn in chess,' 'make sure your hands are dry before touching a light switch,' 'always use black magic marker on white paper'). We find that the strategic level is one of the most useful ways of talking about problem-solving. Furthermore, we find it useful to define two different kinds of strategies—**heuristics** and **algorithms.**

operation

An operation is a **physical** action (or series of actions) that produces change. An operation is a descriptive process, a well-defined, everyday kind of change. Strategies must be translated into operations in order to be implemented. For example, you may want to use the strategy of 'listing,' but still have to decide what operation you are going to use to implement the list; for example: writing by hand, typing, dictating, editing, or tape recording.

heuristic

A heuristic is a strategy that might be helpful to solve a problem but does not guarantee success. For example, in the anagram problem, 'organizing' letters alphabetically or 'combining' in typical endings and then 'playing' with them were all heuristics that might have been helpful but did not guarantee success. You must constantly judge the success of a heuristic from the feedback you get after implementing the strategy and then evaluate whether you should repeat or change heuristics. The list of strategies in the Appendix are all heuristics: 'purge,' 'list,' 'defer,' etc.

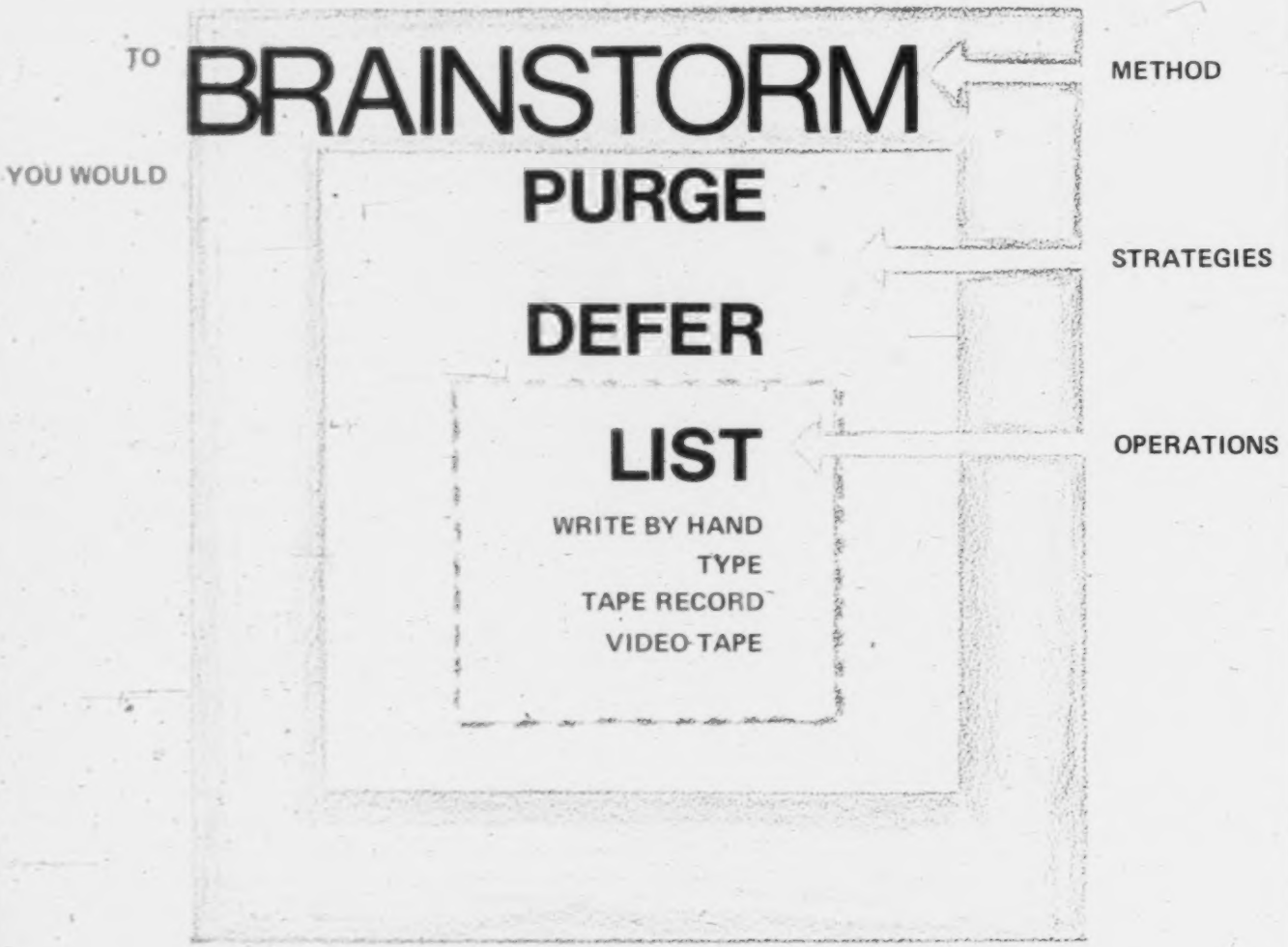
algorithm

An algorithm is a strategy that will guarantee some kind of clear response if completely implemented. For example: to systematically try all the possible combinations of the letters in the anagram problem. Most open-ended problems do not lend themselves readily to being solved by algorithms.

PROCESS

- OPERATIONS — PHYSICAL ACTION OF STRATEGIES
- STRATEGIES
  - HEURISTIC
  - ALGORITHM
- METHODS — SERIES OF STRATEGIES

EXAMPLE:



solving problems

Take a look at the way you approach your problem-solving: can you discover any basic principles? When you first encounter a new problem, do you feel confident about being able to solve it, if given enough time?

Is there anything predictable about how someone else will cope with a problem? Do you know why certain people always seem to produce innovative solutions to problems? What do they bring with them that enables them to adapt to every problem situation? Are they just brighter than most of us, or have they learned something that we have not learned? Is there any relationship between IQ and how well someone can deal with difficult open-ended problems? Why do we call someone rational, methodical, and logical, and someone else spontaneous, irrational, and intuitive? Why do the solutions of these two groups of people always seem to differ?

Look at children. One day they cannot figure out how to get blocks to stand on top of each other to make a 'building,' and the next day they learn something and can construct all sorts of things. What have they learned?

There are no simple answers to these questions. But it does seem evident that there is something called problem-solving ability. People have a general knowledge of how to solve problems. There are no rules or strict outlines for problem-solving, because there is not one 'right' way to solve a problem. You saw that with the anagram problem. Rather, there are tools you use—tools you know how to handle and adapt to different problem situations.

Consider the analogy of the carpenter. A carpenter has a tackboard full of tools in front of him. Each one has a range of uses and limitations. The carpenter has used them all in a variety of situations. When he bought a new spokeshave, it took him a while to get used to it. He did this by experimenting with it on many different kinds of woodworking problems. When he bought a new lathe, other problems became easier for him. Before he bought it, he did not even try to make table and chair legs with a rounded section; now, this lathe permits him to do things which he could not do before. In each case, once he has mastered the use of a tool, it has become almost an extension of his hand. When a piece of wood is rough, he reaches for the plane or sandpaper without consciously stopping to think about it. Given almost any problem, he can quickly decide which of his tools to use to resolve it. In many situations he knows there is no one right tool, but he may prefer one because he is more comfortable with it, even though another one might be simpler to use. His know-

ledge and skill with his tools determine a substantial part of his overall ability as a carpenter.

Just as the carpenter has his tools, so we have mental tools. In the same way, our ability as thinkers is dependent on our range of skill and experience with these tools. These tools are what we have defined as strategies, and they are part of what we call our **process repertoire**.

IDENTIFYING THE PROCESS

It is obvious that you already have a process repertoire, or you would not have survived in this world of problems. But have you ever stopped to examine what is in your repertoire? Not many of us have. One of the reasons for this is something we have mentioned earlier: we have not had a language and vocabulary describing these processes. Realizing this, we are then prompted to ask an important question: would it help you as a thinker and problem-solver to be aware of your process repertoire, as well as other strategies you could acquire?

Knowing what tools you are using, why they are or are not working, and learning about alternative tools can be very useful. If you are using a certain set of processes every day, it makes sense to know what they are.

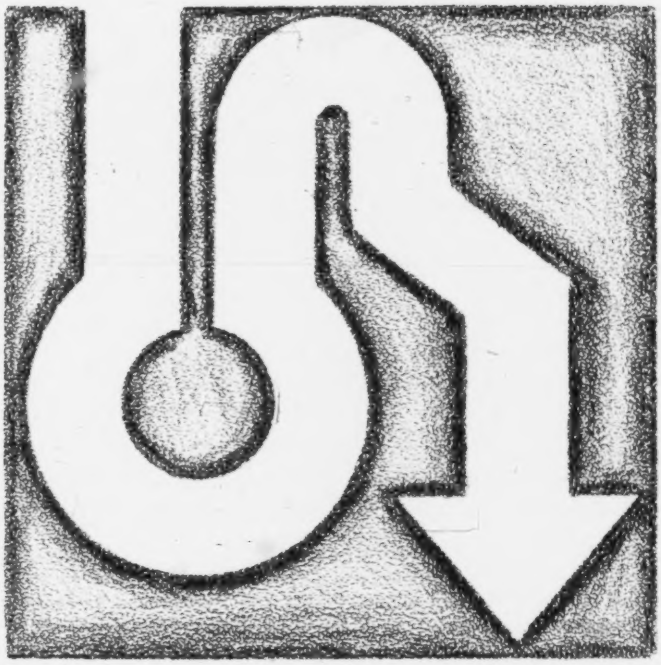
Assuming you have a process repertoire with some basic strategies in it, is there any way of identifying them, and, if so, are they limited enough to do you any good as a problem-solver? The answer is yes to both parts of this question. The glossary of strategies in the Appendix defines the most important strategies in terms of simple active verbs, and offers some useful information and practice in using them.

This classification in the glossary is arbitrary. A well-developed theory of cognitive strategies does not exist at this time. The list of strategies presented here is the result of a very pragmatic process. Developers of Tools for Change simply documented as many different approaches to problems as possible, and searched for some common denominators. Someone may yet develop a comprehensive theory of problem-solving. However, for the time being, the taxonomy here seems to work. There are very few approaches to problems that do not fall under at least one of these categories.

Most of us do not have semantic labels for these strategies, and, even if we do, it is likely that they do not coincide with the ones in the master list here. The labels used here are arbitrary. They were chosen for their simplicity. These pairs are simple, active verbs with meanings that are commonly accepted in Webster's Dictionary. While not always opposites, these pairs represent two approaches to problems that are in some way related, e.g., dream-imagine. Problem-solving can be seen as a constant balancing process between strategies that approach from different directions. Each direction may have an opposite that is equally valid. The description in pairs heightens this contrast and reduces the total number of concepts to learn.

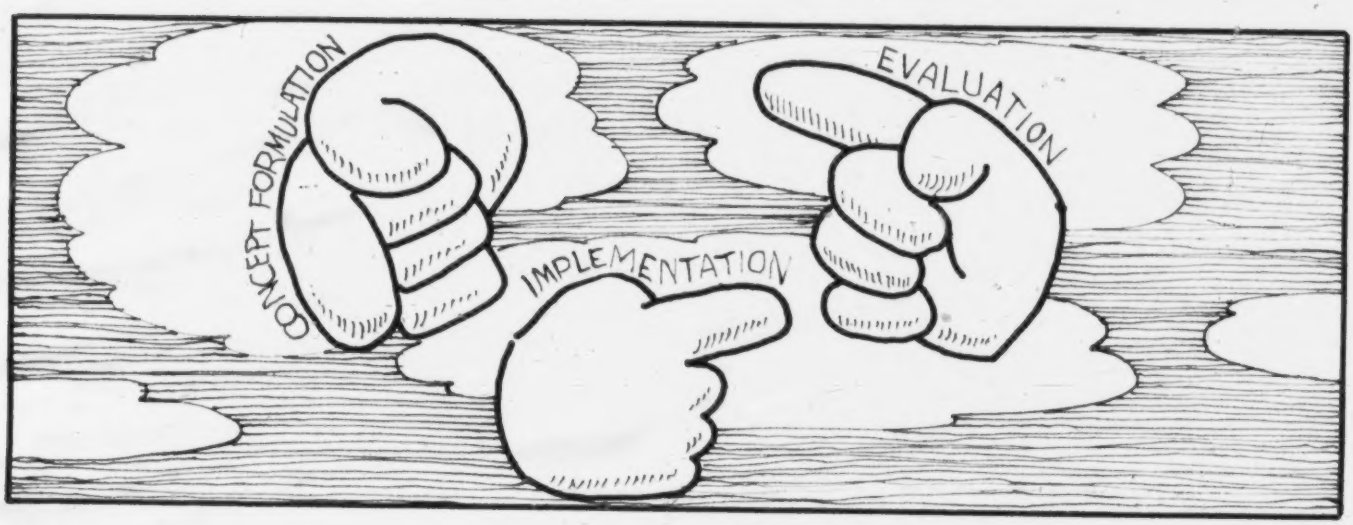
STRATEGIES AT WORK

How can the strategies listed be put to practice in everyday problem-solving? Go back to the anagram problem you tried earlier. As you began to get involved in it, you probably had some immediate ideas or guesses. A certain combination of letters triggered some association, and you had an idea you thought might work. As the first few guesses didn't work, you started examining the individual letters and perhaps reordering them. Each time you wrote them down differently, a sudden possibility may have appeared, and you tested it out. Or you may have become fascinated with one sequence of letters, like ARY, playing with the rest to make a prefix to this ending. The point is that you probably did not follow any real sequence or plan in this case, and that your train of consciousness was certainly not ordered. It jumped around, thought of various things, and poked at the problem much faster than you could record. And yet each jump was characterized by a particular point of view or approach. 'Let's try...', 'Maybe...', 'How about...?' These points of view could be identified in terms of the basic strategies in the glossary.



normal problem-solving is not a well-ordered, sequential process, methodically moving from one point to another in a highly predetermined way.

Problem-solving is characterized by jumps back and forth between many different strategies. Because you don't have the capacity to see a problem from every point of view at once, your mind hops around building a coherent picture. At times it may limit itself to one aspect; at other times it pulls away to get an overview. This process of jumping around is called cycling, and is an essential part of problem-solving.



Closely examining this process of cycling, we see that problem-solving passes through three different phases: **concept formulation**, **implementation**, and **evaluation**. **Concept formulation**: idea, 'What would happen if...?' or 'Let's try....' **Implementation**: the operational phase, writing out, drawing up, computing. **Evaluation**: does it work, do I like it, can we afford it? Then the process goes on to concept formulation again.

There is nothing rigid or predetermined about the sequence of the problem-solving process. What is determined, to a great extent, is the range of strategies that are relevant to a problem. Your own process repertoire represents a more limited set. At one level, there may not be many more strategies than are listed in the Appendix. That is not so important; what is important is that you examine what strategies you are using. If you are having trouble solving your problems, you need to develop new strategies.

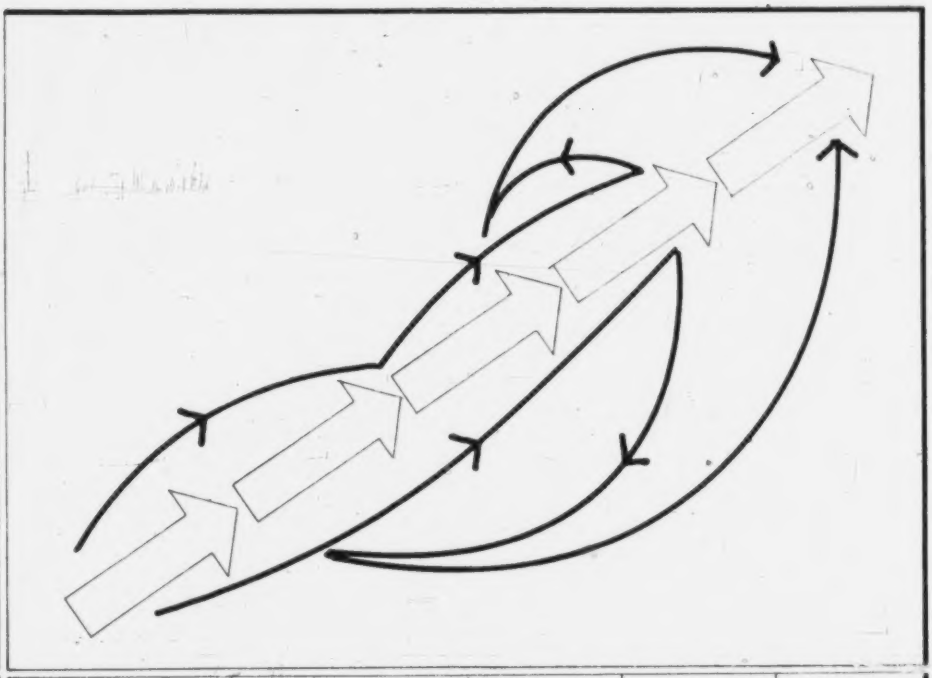
Distinct stages in problem-solving have been recognized for a long time and have been described in the literature of many fields. While problem-solving has been segmented in different ways, the stages most often mentioned are: perception, definition and analysis, planning and prediction, alternative generation, evaluation, and synthesis. All problems do not involve all stages of problem-solving, some, in fact, primarily involve one stage: for example, generating alternative names for a child.

it is important to realize that strategies are <u>not</u> limited to one particular stage of problem-solving.

In fact, as the diagram on page 31 indicates, each strategy is applicable to many, if not all, stages. It is useful to see stages in terms of different sub-goals or sub-problems during the course of problem-solving. For example, during perception, the goal is to see if a problem can be perceived within a particular context; during definition and analysis, the goal is to try to limit and understand the problem; in planning and prediction, strategies are used to map out an attack on the problem and to focus on the future, to see implications; in alternative generation, the goal is to think up potential solutions to the problem; in evaluation, the sub-problem is to make a decision, to choose between alternatives; and finally, in synthesis, the problem is to combine all the sub-solutions and results of other stages into a complete design or solution.

The word 'stage' implies that there is a sequential order, that one stage follows neatly after another. That is not so. The stages are really conventions. In retrospect, most problem-solving does progress generally from perception, through definition and analysis, on to a final synthesis of a solution. During a relatively short period of time, most of our thinking tends to be primarily in one stage. It is useful to be aware of what your goal is at any point in time. Too much cycling between stages can be confusing and wasteful, especially when working in groups. However, description in terms of stages is really a narrow view of problem-solving, and is a product of our desire to order and structure things. Even in the most rigorous of problem-solving methods, the process of coming up with new ideas and workable solutions is extremely erratic and relies heavily on chance, mood, and the particular situation. We recognize a problem, think of a solution, test it out, go back to the definition, change our plans, etc. There is also a great deal of feedback and regression. That is why we often choose to call these general goals in problem-solving 'phases' instead of 'steps' or 'stages.'

SYNTHESIS
EVALUATION
ALTERNATIVE GENERATION
PLANNING & PREDICTION
DEFINITION & ANALYSIS
PERCEPTION



	Perception	Definition & Analysis	Planning & Prediction	Alternative Generation	Evaluation	Synthesis
ADAPT-SUBSTITUTE		●	●	●		●
ASSOCIATE-CLASSIFY	●	●		●	●	●
ASSUME-QUESTION	●	●	●		●	●
BUILD UP-ELIMINATE	●	●		●	●	●
CHANGE-VARY	●	●	●	●	●	●
COMBINE–SEPARATE	●	●		●	●	●
COMPARE–RELATE	●	●			●	●
COPY–INTERPRET	●			●	●	●
CYCLE–REPEAT	●	●	●	●	●	●
DEFINE–SYMBOLIZE		●	●		●	●
DIAGRAM–CHART	●	●	●	●		●
DISPLAY–ORGANIZE	●	●	●		●	●
DREAM–IMAGINE	●		●	●	●	●
COMMIT–DEFER	●		●	●	●	●
EXAGGERATE–UNDERSTATE	●			●	●	●
EXPAND–REDUCE		●	●	●	●	●
FORCE–RELAX	●			●	●	●
FOCUS–RELEASE	●	●		●	●	●
GENERALIZE–EXEMPLIFY	●	●		●	●	●
INCUBATE–PURGE	●	●		●	●	●
HYPOTHESIZE–GUESS	●	●		●	●	●
LEAP-IN–HOLD BACK	●		●	●	●	●
LIST–CHECK		●	●	●	●	●
MEMORIZE–RECALL	●		●	●		●
PLAY–MANIPULATE	●		●	●	●	●
PLAN–PREDICT		●	●		●	●
RECORD–RETRIEVE	●	●		●		●
SEARCH–SELECT	●			●	●	●
SYSTEMIZE–RANDOMIZE	●	●	●	●	●	●
TRANSFORM–TRANSLATE	●			●		●
VERBALIZE–VISUALIZE	●	●		●	●	●
Work Forwards–Work Backwards	●	●	●		●	●

how do you teach process?

For the past two years Interaction Associates, Inc., has been grappling with the problem, 'How do you teach process?' This book has been put together to assist students and teachers become more productive, flexible, and self-confident problem-solvers through awareness of the processes and other conceptual tools they individually use.

Games provide one of the contexts in which to initially experience a process. Play is one of the first heuristics that we learn as a child. In fact, it is critical to concept learning. Play is enjoyable and non-serious. We are much more likely to try something new if we make a game out of it. While winning is a strong motivational force in game-playing, losing does not really hurt. After all, it is only a game.

WHY GAMES?

Games here are not used primarily as a way of teaching content. Rather, they are used to demonstrate strategies at work, and therefore we are not concerned with realism of the content. Students and teachers are given actual problems to introduce the element of reality.

Games may be useful as a way to observe process. The

rules of a game are constraints that limit the number of processes that can be used; therefore, intense contact with a few heuristics is more easily experienced. For example, the game of 'Twenty Questions' stresses the use of the heuristics of 'questioning' and 'eliminating' and does not require the heuristic of 'diagramming.' The rules of the game restrict feedback to 'yes' and 'no' statements, and so the effectiveness of particular kinds of questioning can be easily tested.

As problem contexts, games are also limited in the sense that variables are fewer and can be seen more clearly than in real life. In 'Twenty Questions' there is only one answer to be found, and you know when you have found it. In a game, success or failure can be more easily traced to a specific move. In the complexities of daily living, it is harder to isolate cause-and-effect relationships.

Games are also powerful as a way to 'break set.' Our educational system has built into it many traditional sets of conditioned responses that inhibit experiential learning. Teacher-facing-rows-of-neatly-aligned-desks presents a mental set of confrontation and one-way communication, whereas when a student has just beaten his professor at a game of 'Scrabble,' the professor does not seem so imposing anymore.

Games that involve groups encourage communication of strategies. If groups are broken into 'observers' and 'players,' with the roles being switched periodically, the 'players' are forced to explain their strategies to their replacements so the plan can continue.

By playing a series of different kinds of games as a team, students will begin to appreciate the value of having different types of thinkers on one team. A team with only good 'figure-outers' will not be very successful in games of skill and fantasy. Hopefully, each student will become aware of his own process repertoire and abilities and become curious about other ways of doing things — if only to become a better player.

One of the most important reasons for using games is that they provide a context within which people can discover for themselves the basic tools for change. Once a person is aware of the basic heuristics, he can be shown how most of them can be used in a series of well-chosen games or experiences. Showing a student that he already uses a particular heuristic in some aspect of his own problem-solving may have strong psychological effects: he is not being presented with something totally new; rather, what is being revealed and encouraged to develop is a process that is already latent within him.

RESULTS

The evidence from pilot workshops with teachers so far has shown that games work extremely well. In one session with a large group of teachers and students using only simple games like 'Twenty Questions,' the group generated almost word for word many of the heuristics identified here. They were intrigued with this new way of looking at what they had done, and immediately began making connections with other problems for themselves.

However, having experience with a heuristic **only** in a game context is not enough to enable a person to fully understand its powers and limitations. **Transfer** must be encouraged by making connections between the application of the heuristic in a game and applications in many other aspects of life. While there is no known scientific proof, it is believed that transfer is facilitated by attaching a semantic label to a heuristic, and reinforced by applying it in different contexts. It is not known how we locate a process when we are searching for a new strategy in problem-solving, but there is strong indication from other types of information that semantic coding plays an important role. It seems that a person is more readily able to recall a particular heuristic if he has previously labeled it with a simple active verb and has experience with this process in many different problem contexts.

It also seems that an understanding of heuristics will be enhanced by seeing them in a context of a working model of mental processes. It is called a 'working' model because it includes knowing only those facts about the mind which are helpful to understand individual difficulties in problem-solving. For instance, the power of listing items can be understood when you realize that you can hold only seven plus-or-minus two pieces of information in short-term memory. It is helpful to know that seeing is a constructive act: that you build up an image. Learning to see is learning how to construct different kinds of images. Therefore, by presenting from time to time facts about mental processes from a working model, we will satisfy students' natural curiosity about themselves and help them to see the processes they are learning about in a larger context.

TESTING THEORIES OUT

In order to test heuristic theories, we introduced Tools for Change in a variety of ways in a number of different learning situations. Classes were set up for students on sixth grade, ninth grade, and graduate school levels. There were about 100 students in all. Most were considered above-average, high potential students.

Teachers involved in developing Tools for Change had an opportunity to test their current ideas and develop new ones for a future-oriented teaching course. They had a chance to determine strengths and pitfalls of their approach. Some of the results and conclusions reached are following.

process bias

According to observations, by the sixth grade most students have a definite process bias. They prefer, and have a better grasp of, certain strategies; therefore, certain problems are easier for them to handle. For example, some students are better at logic problems, while others are more competent in open-ended design problems.

That most people have certain dominant strategies and prefer certain kinds of problems is not very surprising. We are constantly labeling each other in our own process language. We say, 'He plans too much,' or 'He never plans enough,' or 'He's always dreaming,' or 'He's always checking things.' or 'He never checks enough.' We think of each other often in terms of process, and there are usually a few dominant ones that come to mind for each person. The same is true of problem preferences. Some of us like to work on logic and mathematical problems, while others of us prefer to deal with social problems or design problems. There is a definite relationship between our dominant strategies and the kinds of problems we feel most confident of solving. People who are good at logic problems, for example, have a good grasp of the 'right-handed' or scientific strategies—strategies which include **working forwards, eliminating, varying, systemizing, comparing, relating, diagramming,** etc. On the other hand, those who are more competent graphic artists tend to have a better grasp of strategies, such as **dreaming, imagining, visualizing, incubating, associating,** etc.

From the beginning of the first pilot test of Tools for Change, our teachers became very conscious of the natural process biases of students and the effect of this bias on curriculum activities. The sixth grade class had a particularly wide range of dominant processes, almost to the point of caricature. For example, one of the games we played was 'Hangman,' in which elimination is a dominant strategy. Ming was a student who had a hobby of coding and deciphering; her mind was like a bear trap. Ming kept winning game after game, and when it came time to externalize collective strategies, the teacher found that she had a particular approach of her own: she had memorized the frequency table—an ordering of the frequency of which each letter appears in an average page of text—and with no other clues, she would begin working her way through this table with increased probability of success. On the other hand, when Ming was faced with a design problem of spanning two feet with a bridge made of six inch swab sticks, she ran into great difficulty. The open-endedness of the problem, and the need for other strategies, threw her off balance.

Joseph was just the opposite. He had great difficulty with logic problems, but was extremely inventive when it came to design problems and problems involving categorization. He had learned the characteristics of almost every fish known to man, and in his spare time he would design plans for zoos.

Our present school system tends to reinforce these process biases by compartmentalizing subjects that, in turn, require dominant strategies, as well as by the whole process of specializing. Students very quickly begin to identify themselves as 'mathematicians' or 'historians' or 'artists,' and therefore tend to take courses which focus on a particular set of strategies.

It is important to remember that any heterogenous class will have strongly divergent process biases. There are exciting possibilities of student interchange, but there is also the danger of boring or turning off students by focusing for extending periods of times on limited strategies or problems. This problem is discussed in more detail under **LINEAR TEACHING APPROACH.**

inquiry approach

The inquiry approach (setting up experiences where students can discover certain strategies for themselves) can work quite well if the experiences are interesting and have meaning for the students. But this approach depends on the teacher's ability to handle the post-experience discussion.

The inquiry approach is based on the concept that for most problems, certain heuristic strategies work better than others. For example, in a game like 'Twenty Questions' it is useful to ask questions that eliminate whole categories of answers, instead of starting right off guessing at the answer. It is fairly certain that if someone is good at playing 'Twenty Questions,' he is using the strategy of eliminating rather than guessing. It is possible to design problems and games that focus on different sets of strategies. If a student can solve a given problem, it is likely that he used the strategy or set of strategies which the problem was designed to exercise.

Over the last year and a half, we have categorized existing games and problems and designed new ones. These focus selectively on various strategies included in our Access Library (see Appendix). For example, the game of 'Least Remainders' stresses the strategies of **planning, predicting, working forwards, working backwards**; the game of 'Jotto' focuses on the strategies of **varying, systemizing**; certain select design problems focus on the strategies of **defining, diagramming, visualizing,** and **changing point of view.**

The inquiry approach, then, presents the student with a certain set of problems that focus on common strategies. It gives him time to work on them either alone or in a group. Usually the experience incorporates one or more structuring devices that require the student to describe verbally or graphically how he is approaching the problem and why. After a class works on a problem for a reasonable amount of time, students share with each other their experiences and personal strategies used to approach the problem. Then, after all the students have shared their experiences, the teacher can do one of two things: lead them on to a new problem, or start a discussion which analyzes the class experience and generates a few general strategies for dealing with the specific problem.

Teachers agreed that the inquiry approach is the most effective way to selectively teach a particular strategy in an experiential way. For example, we have played the game of 'Battleship' at the sixth grade, ninth grade and graduate school levels. This game is easy enough for a sixth grader to play and yet challenging enough to hold the interest of a graduate student. At each level it has been effective in teaching the concept of feedback. It also effectively showed the powers and limitations of the involved strategies: **recording, planning, testing, predicting,** and **eliminating**. During the post-experience discussions, all age-level groups demonstrated they were aware of using those strategies.

The danger of the inquiry approach is that it can become overly contrived and teacher-centered. At first it is easy for a teacher to be too eager to have the students understand concepts about strategies and become manipulative. This is what happened with teachers in some of the first Tools for Change classes. Later they began to see that just having the students involved in the problem and beginning to externalize their approaches achieved intended awareness.

They found it was often more effective to let the students go through a series of similar problems before asking them to make abstract strategy connections. There is sometimes a fine line between allowing the student to discover something for himself and leading him by the nose. It is also important for the teacher to be willing to deviate from his teaching objective involving one process strategy if the students become involved in a discussion of another. However, since simply experiencing the problem is not enough to achieve the process awareness needed, some kind of discussion on the problem is important. Discussion is critical in developing abstract, universal tools that we are attempting to teach.

linear teaching approach

There are many severe limitations to teaching a strict process-by-process course in problem-solving. Teaching the course beginning, e.g., with logical strategies, such as building up and eliminating, then moving on to more open-ended strategies, like dreaming and associating, had serious drawbacks.

In early testing, Tools for Change followed a very structured curriculum guide. The course progressed methodically unit by unit, concentrating on logical processes. The basic teaching approach used was the inquiry approach. But the limitations were still severe.

The course dealt with logical processes for an extended period of time. Because of this, it turned off many of the students who had other process biases. The units were brought up in arbitrary sequence, rather than in response to existing problems in class. The class lost interest.

Discussions became divorced from real-life, meaningful problem-contexts, because the course dealt almost entirely with small problems and the inquiry approach.

There was too much information about process, and the lesson plans did not allow enough experience to let the concepts sink in.

In the pilot studies, many difficulties arose as a result of lack of experience, lack of good working problems, and lack of well-defined teaching techniques. In later experiments, the linear teaching approach was tried again, that time using more substantive writing problems and coaching help from the teacher. There were still major limitations. It was not that the units were poorly designed, but that they needed to be initiated in response to some need on the part of the class. If the class is currently involved in a planning problem and having difficulty, the unit on planning and prediction has more immediate relevance to them, and their interest level is much higher. One of the major problems with the linear approach was that the order was arbitrary and did not respond to the mood of the class.

Another problem was, that since the initial subject matter dealt strictly with the logical process, the course had an image of being one in puzzle-solving or mathematics. It also had the effect of accentuating the division between those students who were good at analytical problems and those who were much more comfortable with open-ended design problems.

An example of this in the sixth grade class was that while Ming and Elliott thrived on the word problems and puzzles, Vivian and Joseph were intimidated and turned off by them. Moreover, Ross, a rather volatile child, refused to even come to this class. However, later in the term, when the class turned to design problems, Ross fought his way back into the class in order to participate in the bridge-building problem. Had he been given a chance to grow from his own natural strengths initially, he probably would have been more willing to venture into areas of problem-solving that were more threatening to him.

During initial pilot tests, teachers spent too much time attempting to sustain class discussions on the powers and limitations of specific strategies. Discussions ended up more like lectures, and many of the students temporarily retreated into the masks they put on during presentations—a glazed stare. Teachers would ask the class to make up 'strategy sheets' that included a label for a strategy, synonyms, definitions, and examples from different areas of both academic and non-academic life. They found that this approach was too structured, formal, and abstract to hold the interest of all the class for any period of time. Now this information is available to them in the form of the Access Library, and discussions focus on particular applications of a specific strategy when relevant.

From these experiences, teachers learned that if strategy units are to be presented they should relate to the immediate needs of the students; they should stress more student interchange and less discussion by the teacher; and much time should be spent being involved with the particular experiences.

coaching

Coaching is an alternative to the inquiry approach to teaching. Instead of setting up specific experiences, the teacher allows the student to define his own problem. When the student runs into difficulty, the teacher helps him out. By coaching students with explicit strategies, teachers found that students gradually became more aware of their own particular approaches to problems and, in addition, learned new strategies.

The coaching approach developed out of necessity. The inquiry approach assumed interest on the part of the students. The teacher acted merely as a catalyst and facilitator for the student interchange. But the teachers discovered that the students were not willing to participate. For the class to work, students had to be involved in a meaningful problem. Once the students were involved in a problem, teachers acted as a coach. When a student or group of students ran into trouble, teachers assisted by helping them examine the strategies available.

An example of this happened in a sixth grade pilot class during a bridge-building problem. Students were trying to span two feet by constructing a bridge out of six-inch swab sticks. Vivian, a small black girl with pigtails, had been quite disinterested during a previous inquiry experience which focused on the process of simulation. Now she was having difficulty designing her bridge. When she requested help, the teacher asked her what her problem was. She said she just didn't know where to begin. The teacher suggested she simplify the problem and look at it in two dimensions by making a little model. The teacher marked out two feet on a sheet of paper and then had Vivian arrange the six-inch swab sticks in some pattern that could connect the two end points and appear reasonably strong. Her face lit up with joy as she began to see how the simulation strategy could work for her.

In another sixth grade pilot class, Trudy was having difficulty designing a piece of sculpture that would communicate how she felt about trees. When she asked for help, Ruth (the teacher in that class) suggested she might diagram what she was trying to do. She pointed out that this approach might help her visualize her design in her own mind as well as communicate it to her teacher. A few weeks later, Ruth was trying to verbally describe a linoleum block cutter that was missing. Trudy piped up and suggested that if she would draw a diagram on the blackboard, maybe everyone would understand better.

Another student, Jane, was having difficulty thinking up ideas for her project. Ruth, who had introduced the method of brainstorming in an earlier class, coached her by suggesting that brainstorming might be applicable in this situation. Jane tried it and was surprised by how many ideas she could generate. A few weeks later, she came into class one morning and reported with great pride that she had been having difficulty with an English paper, had tried brainstorming, and discovered a novel way of approaching the topic.

use of vocabulary

Both the sixth grade and ninth grade students demonstrated they can learn and use a common vocabulary of processes. However, it is not certain yet whether it is better to let students develop their own vocabulary or to offer them pre-established labels or concepts.

During initial experiments, teachers focused on the use of a common vocabulary of strategies. They found students at all the age levels learned labels for the strategies very easily.

Students are very good at memorizing words. In fact, sixth grade students particularly enjoyed picking up new words and playing with them. It is not very hard to define, for example, 'eliminating' as 'figuring out what you know is not in the solution, and then looking at what's left.' The teachers covered at least twenty different strategies with such obvious definitions. The fact that students were picking up on this vocabulary as well as understanding some of the fundamental concepts involved was documented by Terry Borton of the Philadelphia School System in an article in **Saturday Review** (April, 1970), 'What's Left When School's Forgotten?':

I visited one of the experimental classes at Berkeley High School on evaluation day. The class wandered for awhile as the mechanics of schedules got worked out, and then settled down to a discussion of what processes were most important, and what strategies had been most effective in teaching them. The kids obviously knew the lingo—they talked about problem-solving cycles, alternative generation, and brainstorming—but I was not sure that their knowledge went any deeper than the ordinary ability of bright American students to give their teacher back what he wants. Then someone mentioned 'working backwards'—the process of finding out how to get an answer by starting with a knowledge of what the solution should be, and moving back to the problem. A good-looking girl who had been sitting next to me sucking on cinnamon Red Hots suddenly came alive.

'Monopoly,' she said.

I was a bit startled. 'What do you mean?' I asked.

'Monopoly. We were playing Monopoly, and I was thinking, this is sure a weird thing to be doing in school, and then suddenly I saw it. Right there, playing Monopoly, I was using that process—working backwards. I was thinking about buying a hotel, and working backwards to figure out how to get the money. Me. Right there, playing Monopoly. Wow, it drove me crazy.'

'So you really learned about processes by playing the games?'

'Well, that one I did all right. I never knew I could do that, but now I know. I use it a lot, like in algebra. Sometimes the process comes through, but sometimes it's just playing games.'

Another example of use of vocabulary comes from a student's workbook during the Summer course:

In playing Submarine, I repeated, systemized, and eliminated. I systemized by working out a system to eliminate possible places that my opponent's fleet could be, for example, I called out 'E4' and he said, 'Miss.' I then assumed that the spaces around E4 couldn't contain a ship and eliminated them. I then repeated this system for the whole game.

The project team members found that the use of the process vocabulary infiltrated their daily speaking vocabulary. They often found themselves explaining to someone how to approach a problem and using the words from the **Glossary of Heuristics.** One student reported that he began to see everything he did in terms of some of the concepts he was learning.

It turns out that the process vocabulary is useful to communicate; any categorization scheme that is useful tends to be self-reinforcing. However, the primary educational goal of the course is to help students expand their repertoire of conceptual tools by learning new heuristic strategies. Simply being able to label a strategy is very different from being able to use it effectively. Therefore, it is more important that they can use a strategy and apply it to many different situations rather than just identify it with a specific label. It will take more experimentation to discover the true value of semantic labelling.

difficulty connecting to academic subjects

For the most part, it was very difficult to help the students make connections between experiences in a special course in problem-solving and their academic problems. The kids knew this was not an academic subject, and to bring up a Math or English problem in class had a sense of artificiality. The experimenting teachers now believe the course connections have to be made where problems are presented—Math class, English class, or wherever.

One of the primary goals of Tools for Change is to help students develop generalized, conceptual tools that apply to many different problem areas. The aim is to make the student aware that the strategy he discovered in a game or a particular problem can be developed into a powerful tool that can be applied to many of his academic as well as non-academic problems. However, one problem with the course was that it was isolated—both organizationally and in the student's mind—in its own little compartment, in much the same way that English or Math were. It was very hard for teachers to make the point to students that problem-solving was not just another course, but a study of processes that were applicable to all areas of human endeavor.

Students, especially the younger ones, would not really believe that process connections could be related to real life. Showing that such-and-such a strategy could be used in English or Math was not effective. Students have to experience the connections in a specific case.

different sets of needs

Different classes need different teaching approaches. One class in the pilot study was considered 'uncontrollable' and had an initial distrust of any new teacher. Another was mostly composed of 'hip, freaked out' kids who were generally turned off to the system. Teachers could not assume their interest in investigating the nature of problem-solving. They learned that they had to stimulate interest in different ways for different classes.

Some of the kids in pilot classes were basically turned off to the educational system, and teachers could not assume even minimal interest. From the very first day, they were challenged and found that they had to meet the kids' needs and win their confidence before the kids were willing to work in class. For example, one of the sixth grade teachers, Ruth, encountered a pre-established distrust of any white teacher by several of the blacks. Portia, a tall, gawky, black girl, came up to Ruth the first day, pulled at her arms, and said to her, 'What are you doin' in here? You're white, you know.' A week later, Ruth met Portia in the Vice Principal's office after he had thrown her out of a class. Ruth began talking to Portia about her interests, and found she was creative in several different areas. Her big problem was that she had no friends. She was always blowing up, had a very bad temper, and no one wanted to stick around with her. As they walked back to the classroom, Ruth asked Portia if she still felt the same about having a white teacher. Portia told her that it was all right now, that Ruth could stay. From that point on, Ruth could work with Portia. Whenever there was game-playing in teams, Ruth would be Portia's teammate. As she became Portia's friend, Portia became more and more involved in the activities and concepts of the class.

At the ninth grade level, another teacher, Chris, found the same antipathy to the school system. He tried to confront the students' needs directly. During the first week he asked each student to make a list of personal goals—things that they would like to accomplish—and a list of problems or concerns that they wanted to deal with.

Goals:

Independence, mobility, thoughtfulness, money, get into the community schools, own a horse, self-survival, get into nature, become more myself, be more open, relate to others more successfully, be more real, burn the pigs, tell the truth about ethnic minorities, gain opinions, stop questioning so much, have worldly discussions, improve ability in crafts, learn about people, get it together, be happy, learn about sex and love, make friends and keep them, discuss the drug experience, change, decrease inhibitions, play the guitar, learn to cope with school better, make others happy, have deep talks, change way of life.

Problem Areas:

Red tape, environment, family relations, phoniness, up-tightness, smog, teachers, stereotyping, people, school, my age, physical appearance, police, the Man (authority), the city, fighting, Telegraph Avenue, drugs, tests and grades, doubt, rip-offs, embarrassment, homework, writing, dishonesty, hurting others, bigotry, hassles, depression, over-production, budgeting, money.

It is interesting to note that only a few of the concerns in this list are related to schoolwork or academic subjects.

Chris also reported many anecdotes of how, once something was done about these needs, students became more receptive to other activities. For example, Terry—outspoken, brash, aggressive—was able to give honest and straightforward feedback from the beginning of the class. Throughout the course she showed much inner confusion, which centered on a negative relationship with another person in the class. However, she did establish a warm relationship with Chris. This enabled him to coach her and help her externalize the problem by diagramming her love-hate relationship. By the end of the semester, she had opened up considerably to others in the class and seemed much less brutal towards those around her. She also became involved with a music project; she arranged and presented a number of songs to the class.

differences in older students

The older students, who had much experience to refer to, were more easily involved in intellectual discussions about particular strategies. Graduate students could carry on reasonably long discussions about specific approaches to problems. Moreover, a graduate student had a definite set of needs and could see relevance in process awareness. Some students in an environmental design course reported an increase in their ability to design.

The inquiry approach is more effective on an adult level than on a younger level. Discussions after the experience can be more abstract and intense, which means that more information can be presented to adults than to sixth grade or ninth grade students. Need, again, is the motivating factor. Some of the adults in the pilot classes were first and second year architectural students who were desperately trying to pick up new design tools in a curriculum which focuses mainly on problems and solutions. Other adults were teachers who attended a pilot workshop. They too were faced by a pressing sense of need. They were finding their curricula and teaching approaches rapidly becoming obsolete in this changing world, and were already coming to the conclusion that process awareness was one of the truly relevant things they could offer their students.

The graduate architectural students who came from disciplines accustomed to dealing with abstractions, but who wanted new conceptual tools, were most eager to accept Tools for Change. The students working on design projects reported positive effects on their own design process.

For example, one student reported, 'I feel I have gained some very useful insights which are directly attributable to the course. I have a better understanding of ways to go about looking at my conscious and perhaps even my subconscious. I feel...this course is only a first step, or perhaps more accurately, a long deliberate step, among many other steps, towards understanding myself and others.'

Another student said, 'The subject matter of a course in heuristics is admittedly easy and is something we all should have learned by the sixth grade (at the very latest). For various reasons we did not learn this basic tool, and it is reasonable that we devote some part of our time at this point in our continuing education to familiarize ourselves with these techniques. Our purpose in studying heuristics is two-fold: first, it may be a valuable aid in our own work in problem-solving (whether specifically related to the design field or not), and second, it can also be of great help in interpersonal communication and also group problem-solving.... The study of heuristics, then, is a worthwhile endeavor.'

change in motivation

Motivation for learning has changed. What has long been a primary motivation for kids—to do well, to beat the system—no longer exists in certain classes. Most students in the public school system know that they will probably be graduated regardless of what they do, so teachers cannot appeal to grades as any kind of motivation or threat. This means that the problem given to students must be meaningful to them. Also, it is important to point out to them the relevance of what they are learning. A problem-solving approach lends itself to this kind of demand.

Students' interest is not a reliable motivating force. If they do not like what is going on in class, they simply do not get involved. For example, one day during the third week of a pilot class, the teacher, Ruth, was in the counselor's office. Mike, one of her students, was there too. He had been thrown out of his Spanish class. She heard him say to the counselor that not only did he hate his Spanish class and his Spanish teacher, but that he hated the school in general. The problem was not that he did not want to learn anything, but that he just never was given a choice about how to learn, and how to define his own problems. He said it really did not matter in any case, because he knew the school would have to pass him on since they could not afford to hold anyone back. He knew, as did many of his classmates, that the school, for academic and social reasons, had to graduate each student. However, later Mike asked Ruth to tutor him in Spanish because he did want to learn. With help, Mike progressed very rapidly and soon caught up with the rest of the class. He originally had a reputation of never doing homework and never volunteering for anything in any of his subjects. In one class he refused to even speak at all. While he had started off this way in the problem-solving class, things had changed by the end. Three weeks before the end of school, Mike came up to Ruth and asked if he could do a special project. He volunteered to do it after school hours, and over the next two weeks completed his own research project on dogs, which included several field trips to the local dog pounds.

Teachers found over and over again that on both the sixth and ninth grade levels, students were capable of intensive periods of work and involvement, when given a chance to define their own problems. They also discovered that unless a student is involved in a problem and needs help, he is not ready to look at his own problem-solving processes or seek new ones. By the end of a test term, however, many of the students had defined and implemented some project of their own. Then, with the students motivated, teachers had a chance to act as coaches in the problem-solving process (see **COACHING**).

carry-over from spring

The design students who took the course in Spring and returned to the design studio the next Fall were able to externalize their thinking more easily than their classmates who did not take the course. They continued to find relevance in becoming more aware of their problem-solving strategies, and some reported positive effects on their own design ability.

The following is a quotation from the diary of Ethan, the teacher at the graduate level:

Today I saw some tangible proofs of the value of a process approach to teaching. It surfaced especially in two of my students from the Spring class. Judging both from their work and from their comments, it is clear that they are benefiting from becoming aware of the processes they used to deal with their design problems.

Case 1: Pier mentioned during the review that it would have been much better if the house design project had had as the client a person in the class rather than the designer himself. The problem stated that each person should do a design for himself. Pier suggested that each person should design a house for a classmate. The rationale for this was that by having to work with another person as the client, the designer would be forced to be more explicit about what he or she was doing, be able to externalize the design process more effectively, and thus be able to learn a great deal more about the design process than if he were only working for himself. This was the gist of her comments, and they indicated to me that being aware of the processes she used to deal with problems was an important consideration in how she would like to see problems structured.

Case 2: Carol demonstrated via the presentation of her project that she had gained a great deal from a process awareness approach. While many of the students presented classic, final drawings for the review, Carol presented her design process to the class, in addition to a model of a house which was clearly evolved rather than produced. It was clear from her presentation that being conscious and explicit about the sequence of processes she used to move toward the design solution enabled her to develop a solution which clearly met the various criteria of site condition, slope, family needs, intuitive feeling, etc. It was also clear that many of the other students benefited from Carol's sharing of her own processes with the rest of the class.

Two points were reinforced for me today: one, that people previously involved in process awareness (Spring quarter class) are being helped by it now, and two, that experience and externalization of personal process must help a person become a better problem-solver.

process and teacher training

The current goal of the Tools for Change program is to teach teachers how to become aware of their problem-solving strategies so that they, in turn, can develop such an awareness in their students. It is the aim of Tools for Change to help students become better learners. It seems most practical to do this by first helping teachers.

The methods used have their roots in a desire to have the teacher teach in the same informal, individualized manner that students should use in becoming aware of process. Teachers are encouraged to develop and shape their own program of becoming aware of process, to decide what to do, what to read, what kind of projects, games, or learning experiences to use. This will, hopefully, make them better able to experiment in the use of process and process awareness in their classrooms. At the same time, it should help them develop methods to let learning evolve out of their students' interest and the current, moment by moment, context of learning. The teacher is expected to mirror the same sequence the students are expected to follow, namely to come to an awareness of process through existing problem strategies while seeking ever new ways to expand process repertoire.

Beginning in the Spring of 1971, several different approaches to teacher training were tried. The schools involved were Berkeley High School (West Campus) in Berkeley, Serramonte and Jefferson High Schools in Daly City, a suburb of San Francisco.

Diane Streeter, a Drama and English teacher at Serramonte, gives this description of her experience with Tools for Change:

the process of "discovering" process

diane streeter

BACKGROUND

Setting: Music room of Serramonte High School, Daly City, California, a room with no windows, wall-to-wall carpeting, high potency fluorescent lighting, and an over-all sterile appearance.

Time: 4:30 p.m. A particularly unpleasant faculty meeting (if one can be worse than another) is about to end. Inter-faculty fighting has just been resolved in the usual fashion: the principal commands. Amen.

Characters: The entire Serramonte faculty, administration, and a bunch of outsiders who claim they are representing something called Interaction Associates or Tools for Change, or something. Let's not forget the principal of this drama, me, Diane Elizabeth Church Streeter, teacher of English, Speech, Drama, Humanities (and History, if ever asked), who is presently dying to go home.

Raise Curtain: The group of people from Interaction, Tools for Change, is making an appeal to any member of the Serramonte faculty who feels he or she might be interested in studying about process and how individuals make decisions. Their presentation is disorganized and the faculty is restless, but a few words seem to strike some sparks in a few of the heretofore dying teachers. The concept of some sort of systemized study of my own processes—hmmmm.

I personally am really half asleep, but decide to file this under think about it later and go home. I did both.

The rest of the background can be summed up by saying that at this point in my life I felt that I was great at conceptualizing, abstracting, and creating, but felt a need for a little structure and method in my life. I'm not sure that this was what was being offered, but I thought so and, after talking with members of the teacher training team, signed up to participate in their workshop, Tools for Change. I think it is important to be aware that my motivation was one of a personal more than a professional nature. I figured if I was helped personally, it may or may not spill over into my professional endeavors. I didn't care—I just wanted to receive the additional input for myself. (This was early in the second semester of the school year, and shots in the arm are desperately needed by most teachers at this time.)

Experience: The workshops were based on the experiential mode of learning, and this was literally 'right up my alley.' I related very well to what was going on.

I liked the informal atmosphere with the emphasis on what we were doing, not on externals. I began by actively participating in the experience of doing, but keeping my comments back until I had more information for my mental model. A friend whom I rode to the meetings with thought it unusual for me to be so quiet at that time and so did I, but I realized that observing worked well for me the first two meetings. Besides, I was at last learning something about my own processes in problem-solving. I realized that I used various combinations of strategies with different problems. In the case of the workshops (one and two) I was committing myself, but deferring as far as verbal comments were concerned, until I felt I had enough information in my slowly growing mental model of what this present experience was all about. I had engaged in a modified version of Leap In. I had Leaped In when I Committed myself to the workshops, but then I Held Back, on verbal comments while I gathered information, Incubated it, Tested it in my personal life, and began to construct a realistic list of objectives for myself.

It was important for me to be aware of the progression of usage of the material I was learning. I incorporated it first into my personal self—then into my interpersonal self—then into my group self (both in the classroom and in the workshop group). A period of time—perhaps three months—elapsed before I ever tried to utilize what I had slowly been learning in the classroom.

My interpretation of this is that in my particular case, this was totally new information for me, and I had to amass a considerable amount of it before a large enough construct was developed in my mind for me to make transference into a classroom. I have twice before mentioned mental models; I borrow this phrase from John Holt, and it is a useful image for me. It might be considered analogous to going to a movie. You must take in a certain amount of information before you can make any statements about what is going on or incorporate it into the larger body of your own consciousness. So it was with Tools for Change. It took a considerable amount of time for all this to begin to fit into my consciousness in a useful, workable way. In fact, it took not only time, but added motivation in my case to force me to make the transference to the classroom.

Motivation: Process awareness fit into my personal life, almost from the beginning; I was ripe for it. I wanted it. However, teaching it to kids or making use of it in the classroom was another story. I realized I was motivated, but I am also well aware that not everyone else is motivated in the same direction, especially my students. So I sat on it all for awhile. Then I missed a three day weekend work-

shop. I did not want to miss this and tried desperately to learn what I had missed. No one seemed able to explain it to me, except to explain the structuring device of fantasy. I was crushed. I hadn't wanted to 'miss' anything. Quickly I went back over all the materials I had amassed and all my notes on each workshop I had attended. Then I had Jackie Yokote over for dinner. She was a member of our workshop and a personal friend. She tried to tell me what had gone on, but it just didn't seem to come out right. We both agreed that one had to 'experience' this information. She did try and explain fantasy to me in more detail. Zap, I went back to my written information and felt very unhappy. So, I went to bed.

Outcome: The next morning I had to face my Business English Class and once more hassel through grammar. Ugh! They hated it, and so did I, but they had chosen the class because they felt they need the grammar. I hadn't chosen it at all; it was assigned. In the car, my head full of information began starting to fall into patterns. (Incubation) Flash! Why not use the method of fantasy to help the students with grammar. How? What if a student who was having trouble with parts of speech, phrases, and clauses could experience being those little grammar impossibilities? Let's try it.

Class Experience: The class was divided up into those who fairly well understood grammar and those who wanted review. The expert group did independent projects and the other group stayed in class.

In the weeks that followed, the class members went through structured fantasy experiences where they fantasized they were Nouns, Verbs, Adjectives, Adverbs, five types of Phrases and two types of Clauses. At the end of a month the students not only understood parts of speech, but were anxious to explain to the outside project group just what they had learned. My process awareness coupled with their excitement and new level of self-esteem helped to uncover some of the process fixations and biases that had previously existed in the classroom. Together we learned why grammar had been so impossible before. Process understanding led our way. The strategy of Work Forward is basic to our culture. If no other strategy is known, it is the one which is relied upon. We found that we had been using that strategy in trying to identify parts of speech in a sentence or group of sentences, even though it was a totally inefficient and non-useful strategy to use. The students developed a set of strategy groups for attacking various grammar problems with the idea that though these worked well for them, they wanted other students to be aware of their own process biases and develop their own packages if necessary. Students and teacher alike became very excited and hated to see the term end.

Comments like 'This is the first time I ever felt I know something,' and 'It's easy, really easy, I thought I was so dumb, but I'm not' filled the air. I stopped dreading Business English, and so did they. In fact, they actually came early to tell me about their personal experiences with fantasy and how their understanding of process and grammar was helping them in other classes.

SUMMARY

There really isn't much to add. It is my belief that motivation, a teaching mode that was comprehensible to me, and my own desire for growth and change made this program valuable to me. That process awareness can be useful to anyone seems to be a fair statement, but I would add that not everyone will want it. So concentrate on those who do.

SERRAMONTE AND JEFFERSON

At Serramonte and Jefferson the approach was heavily based on 'inquiry;' which proceeds from a simple premise: a good class in process is when the students come in, work throughout their classroom time with an awareness of how they learn, and seek constantly to better understand and integrate these processes into their lives. The assumption is that process literacy is a human faculty, everyone can do it, and the job of the teacher is to assist everyone to understand how to do it.

The teachers were not coerced into learning process. The authority exercised by the 'trainer' was that of the peer. It was assumed that the training proceeded from 'where the teachers are,' i.e., their particular skills, confusions, anxieties, and level of teaching satisfaction. The trainers were not 'experts'; rather, their role was to facilitate the exploration of the individual teacher into process and process awareness.

If Tools for Change succeeds in such an 'inquiry' form, teachers will:

1. Become more aware of the strategies they use in problem-solving; their own process biases; their own styles of operating and other people's styles. They will be more tolerant of students with different process biases.

2. Begin to see a close relationship between Tools for Change and their own lives.

3. Use things they've learned to deal with problems they encounter at school and in daily life.

4. Discuss their own strategies and processes with each other.

5. Use strategies and methods to teach more effectively.

6. Function more effectively in group problem-solving situations; learn to act as facilitators, and use the resources of a group to help solve difficult problems they face individually.

7. Begin to question and remake Tools for Change, feeding in new perceptions, ideas, etc.

8. Encourage students to externalize their mental processes.

9. Focus on strategies in lesson planning that might require and will include some time for discussion of strategies and general processes.

10. Develop new structuring devices, new ways to teach process.

BERKELEY

The Berkeley approach involved both teachers and students in a program that had more 'structure.' There was, in other words, a curriculum (for example, emphasis was placed on such things as communication, process bias, and group problem-solving), and the emphasis was more on the strategies themselves, and practice in using them. Four staff members from Tools for Change met with seven teachers and six students two days a week with the following objectives:

1. To allow participants to become aware of the existence of heuristics and understand their significance (i.e., implications for learning, problem-solving, theories of 'intelligence,' etc.)

2. To familiarize the participants with at least the group of strategies Tools for Change experiments had identified in prior work so that individuals could add to their personal repertoire of strategies.

3. To allow participants to gain the ability to recognize when they were using a strategy and to be able to externally describe the process.

4. To develop a common language for describing the process/strategies to facilitate sharing and communication among the participants.

5. To work with participants in developing the ability to transfer a strategy from one experience to another.

As a result of these five objectives, it was expected that the participants would:

1. Note an increase in their own, individual problem-solving and learning abilities, and therefore...

2. Express the desire to bring the Tools for Change approach to teaching into their classrooms.

Results in the Berkeley program were mixed, although the consensus was that simultaneously teaching teachers and students created problems that made for a difficult learning situation. For example, with both students and teachers there at one time, the carry-over of concerns from the school was greater, and it was difficult to keep everyone focused on the specific tasks. Students did serve a very positive role, as their tolerance for irrelevance was very low. Their presence did much to direct efforts on the basic problems of learning.

The range of subject matter for the teachers involved in all three programs was quite wide and included English, Math, History, Physical Education, and Shop. It was discovered that the teachers could learn to focus on process and were able to carry over some of what was done in the workshops to their classrooms.

In summing up the Berkeley experience, teacher-trainer Mary Sawyer stressed what had been learned:

Teachers want coaching, a sense of direction, and a variety of common experiences with the group.

Teachers want to teach for process as well as for content.

Teachers want to know about heuristics—they told us so. They wanted more than we thought they did at the start.

Teachers want to discuss group experiences after they have them to examine them in the light of specific strategies and personal application.

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importance of process to the world at large

People everywhere are being forced by the sheer magnitude of the problems they face and by the complexities of the modern world to break new ground in their ability to act. We need a better perception of the basis of the problems we face, and a common language of process that will allow us to better communicate our problems and the methods for solution.

The foundations for such a language have been in the making for years. The fields of cybernetics, information processing theory, and computer programming, and cognitive psychology, have been facing the problem of how to describe the characteristics of change. Yet most of these technical languages are too specialized to serve as a common language of process for the average person.

Moreover, whatever the future brings in the way of techniques to solve problems, this era is going to be characterized by interaction: man-machine as well as man-to-man. Interactive computer systems, known as augmentation systems, will, for example, be capable of instantaneously implementing the time-consuming routine work of the problem-solving cycle. Tomorrow, with augmentation systems, most of our time will be spent thinking; while the working out, the drawing up, and the typing of our ideas will be performed by augmentation systems.

Will we know how to use such powerful systems? Will we understand our own problem-solving processes well enough to be able to effectively maintain and use such extensions of our minds? Strangely, while technology may be producing the physical tools to meet the problems of tomorrow, the very presence of these tools creates a new problem by demanding that we better understand our own mental process tools, our 'on-board' tools for change.

importance of process to schools

Given our difficult and complex world, students should throughout their education be concerned with tools for change. A useful language of process could serve as a common denominator by which students could relate the world of experience to the content of the different subjects they study in school. This may be the most powerful role that a set of basic heuristics could play: to relate and synthesize the variety of approaches and methods taught in courses that are often compartmentalized.

In fact, a given heuristic is used in many, if not all, courses, but it is often disguised. For example, the heuristic of 'eliminating' is known in mathematics as the process of 'setting boundaries to solution space' or later as 'linear programming'; in graphic design as the act of 'blocking-in' a design; in the game of 'Hangman' as 'figuring out' what letters are not in the word; and in curriculum scheduling as 'eliminating' courses which meet at the same time. Children often know processes in terms of a specialized sequence of acts like 'goes-into' or 'putting-that-thing-over-there,' but are unable to see that a method used in one context can be used equally as effectively in a totally different situation. By being encouraged to relate many different experiences to a common set of conceptual processes, students may be able to construct for themselves a more coherent picture of how various parts of their curriculum are related.

A useful language of process might allow better communication between administrators, or school administrators and school boards and the communities they serve. Heuristics can provide the basis for better communication among students and teachers. Too much of our thinking is kept locked up in our heads because we have no established vocabulary for communicating these experiences. This situation tends to reinforce our belief that no one could think the way we do. Moreover, we are less likely to share how we think with someone else when we feel we are competing with each other for approval and evaluation.

Because students are not given the language to externalize their own thinking, teachers have difficulty in developing a dialogue about thought processes with them. Students are convinced that the teacher must think 'differently' and would never understand how they think. By establishing a language of process, communication and thought might be facilitated.

Students have yet to become involved as a creative resource in solving educational and community problems. Almost half of the country's population is under twenty-five years of age, a large percentage of which is in school. This is a powerful force—something that the students themselves are just beginning to realize.

Students and teachers should come to recognize that looking at the world in terms of process can be fun. Almost every aspect of life can be seen as a product of some change. By asking ourselves how this change relates to other changes and what we can learn from it, meaning can be found everywhere. A process we use in solving a word problem in mathematics can be related to a process involved in sending the astronauts to the moon. A way of seeing in design can be related to points of view of great men throughout the history of art. Using a common language, students and teachers can discuss how they approach their problems, and become mutual resources. Then, 'sharing' rather than 'lecturing' can become the norm.

appendix

glossary of heuristics

ADAPT

To modify, to make fit the situation, to change part of an existing solution to solve a different problem. Adaptation is a principal strategy for generating a new solution by making relatively small changes in an existing idea or object, or by using it in a very different way than it was intended.

SUBSTITUTE

To put in place of another, to exchange, to replace, to use instead. Substitution aids problem-solving by locating critical elements and replacing them by new processes or parts which may render the problem more easy to work with and solve.

ASSOCIATE

To make use of the natural network of associations in the mind and to use them as links, or jumps for some particular purpose. Associate allows you to get from one place to another, and can lead to new and innovative ideas concerning the particular subject.

CLASSIFY

To group things by sets, to organize by similar properties, to put in a class. Classifying allows us to organize information into sets, label those sets by the common properties of their members, and then conceptually manipulate the labels as abstractions; thereby making the information more manageable or understandable.

ASSUME

To take for granted, to freeze an issue, to accept for the moment, to take on conditionally. Assuming accepts the state of the problem as it is (conditionally), enabling you to hurdle momentary questions and uncertainties, in order to investigate the consequences or to proceed to other transformations.

QUESTION

To doubt, to dispute, to inquire, to challenge concerning validity. Questioning all aspects of a problem including your own solutions is an essential strategy in problem-solving. Self-questioning helps sustain an internal dialogue that can keep you thinking flexibly.

BUILD-UP

To start with something, presumably something that you know is in the solution, and then adding other bits of information to that initial core in any order that comes to mind until you have slowly built up a concept. Build-up allows you to begin to grasp a problem from whatever toe-hold you can get, and provides time to let the solution grow organically.

ELIMINATE

To start with more than you need or want in a solution and eliminating elements according to some criteria. Generally you will know more about what is not a part of the solution, and by tentatively eliminating those parts you will come in closer contact with those parts that are a part of the solution.

CHANGE

To make different in some particular, to give a different position, course, or direction to; to move to another; to replace with another. Changing is a strategy for using other strategies. Changing approach or media is a way of reacting to developments in problem-solving by shifting attack to become more effective and involves awareness and flexibility in your thinking.

VARY

To make a partial change in, to make different in some attribute or characteristic, to change a part in order to test its influence on the whole. Variation can be algorithmic, heuristic, or random. Variation induces chance in order to investigate the relationship of factors in a problem.

COMBINE

To bring into close relationship, to unite, to act together, to bring together several parts. Combining as a synthesis transformation can act on both conceptual and physical materials. Combining and recombining are processes of simplification and synthesis: several different elements come together to produce totally new entities.

SEPARATE

To make a distinction between, to divide, to break up into elements, to sort out, to keep apart. Separate is analytic in the sense that it breaks things down in a problem; it reduces or simplifies the elements so that one can more easily understand or manipulate them. It is the transition from the complex to the simple.

COMPARE

To put two things together either physically or mentally and to look for similarities and differences between them. Compare is important in the phases of analysis and evaluation; and is generally used in order to make a selection or to analyze through contrast.

RELATE

To link, connect, find causal relationship between. To relate is to find the force or theory that governs how two elements or variables behave with respect to each other. It is a critical strategy for understanding a problem and for developing an hypothesis or solution.

COPY

To reproduce, to make another, to imitate, to mirror. Copying as exactly as possible a previous event or object brings direct experience to the learning process. Copying also insures the life of the original design or idea and allows you to make changes on the problem without damaging the original.

INTERPRET

To explain the meaning of, to conceive in the light of individual belief, judgment or circumstance, to say in your own words, to editorialize. Interpreting facilitates learning and understanding, for in order for you to trans-

form an original concept or composition into your own terms, you would have to fully study, take in and assimilate the original idea.

CYCLE

To jump back and forth between several different points or processes, to alternate between several different things, to pass through a series of points in a recurring succession. Cycling is a process by which simultaneity or totality of view can be approximated by alternating between many different strategies. It is a way of controlling change itself.

REPEAT

To do again, to perform another time, to try again, to purposefully try the same process or strategy another time. Repetition is important for minimizing error and is basic to the process of learning in skill development. Many processes can only be successful after several repetitions.

DEFINE

To set limits, to restrict, to place constraints, to describe. Defining clarifies, makes sharper and digs deeper into a problem—thus setting certain limits to the range of possible solutions. Redefining as a reiterative process can be used to widen or narrow the scope of the problem.

SYMBOLIZE

To equate, to set as equal, to stand for, to replace by a symbol. Symbolizing allows you to represent or define an element of a problem as abstractly as possible and then to manipulate it with respect to other elements, concentrating only on relationships.

DIAGRAM

To translate information into qualitative, non-dimensional graphic form. Diagramming is the most fundamental way of recording ideas visually in two or three dimensions. It uses a symbolic and non-representational language to graphically express concepts in terms of relationships, sequences, and simplified features.

CHART

To present graphically in a quantitative, two-dimensional, and consistent form. Charting is really a special case of diagramming, specifically as a method for planning and scheduling sequences of events and activities by describing their relationships in graphic terms and then making projections concerning estimated real time, costs, etc.

DISPLAY

To spread out, to present, to make visible. Displaying is one of the most powerful conceptual strategies related to perception and problem-solving. Graphic display relieves the short-term memory function from the human brain and allows information to be 'remembered' simply by visually scanning, and its information density can be high because it does not need to be read in a particular sequence.

ORGANIZE

To order, to structure, to arrange into some pattern or concept. Organizing is the process of reducing large quantities of complex information into structures that we can handle and remember, often in a hierarchical nature. Organizing allows us to relate one experience to another.

DREAM

To have vivid thoughts, images or emotions during sleep, to make use of subconscious thought during periods of sleep. Dreams can provide valuable understanding of how a problem is being treated subconsciously, for it is only during sleep that your consciousness is turned off. Dream thought can be a source of rich images and hypogogic dreaming can actually be induced and can provide great insights into aspects of a problem.

IMAGINE

To form a mental picture of (something not present), to form mental images, to mentally visualize. Imagining is a powerful way of projecting yourself into hypothetical situations and mentally experiencing them. A developed imagination can be a source of creative visions. Imagery can be used as a mental simulation of an experience or situation, involving all the senses.

COMMIT

To take action for the sake of action, to

bring closure, to take a stand, to make a decision. Committing forces closure and launches you into a new phase in dealing with your problem. It is a stop heuristic (stop what you're doing now and proceed); a strategy of change and action.

DEFER

To put aside, to postpone, to leave for the time being. Deferring judgment or evaluation is an important strategy during periods of alternative generation as it permits you to concentrate on 'thinking up' ideas and not worrying about their ultimate quality. Deferred judgment encourages a positive environment and attitude and prevents budding ideas from being thrown out too soon.

EXAGGERATE

To enlarge beyond bounds of the truth, to overstate, to increase to the extreme. To exaggerate is to push a situation to its limits for some purpose. This can be done for the purpose of making something sound ridiculous or gaining attention or as a procedure for testing the capacities of something. It is the process of moving away from the neutral to the upper limit.

UNDERSTATE

To represent as less than is the case, to state with restraint, to reduce to the extreme, to go to great lengths to de-emphasize. Understate tends to reduce a thing almost to the point of elimination, and in this sense can be used both for emphasis (something missing or a lack of) or for de-emphasis.

EXPAND

To spread out, to enlarge, to work out or develop in full detail, to elaborate. Expand includes both making larger and adding detail. By expanding a part of an idea or solution you are able to blow it up and examine it in more detail, to investigate its implications. Expand can be used to develop a hierarchical organization; the idea of starting with an outline and then gradually expanding until you have a fully developed composition.

REDUCE

To draw together or cause to converge, to consolidate, to diminish, to change to an equivalent but more fundamental or less complex expression, to simplify. By reducing a problem to simple concepts or elements, you can break down a complex problem into a few issues that you can deal with in your mind. Reduce refers to both size and complexity.

FORCE

To exert strength, to use will power, to struggle against an opposing pressure, to work against. Forcing refers to pushing an issue as far as it can go, in order to investigate its validity. 'Force-fitting' is the process of trying to relate a seemingly unrelated idea to the problem in searching for new points of view. Forcing also refers to forcing oneself to continue to follow a given procedure, especially in alternative generation, as we often give up too soon.

RELAX

To make less tense or rigid; to become lax, weak or loose; to seek rest or recreation. Relaxing is the process of releasing mental and physical tension and is often essential for free and innovative thinking. Because of the strong relationship of mind to body, knowing how to physically relax is important, and you should seek a balance between uptightness and total collapse and lack of attention.

FOCUS

To concentrate on, to attend, to channel energy, to zero in on. Focusing brings concentration which is critical for continuity in a line of reasoning and for maintaining complex relationships in the mind. By limiting your area of attention and concern momentarily you can incorporate in-depth observation on that part of the problem.

RELEASE

To disperse attention, to let the mind wander, to let go of control, to flood the mind with thoughts, to keep from focusing on one thing. Releasing relinquishes control of attention and permits the mind to wander freely or to deal with many objects simultaneously. It is an important strategy for breaking fixation and allowing other points of view to present themselves.

GENERALIZE

To abstract, to move in a direction away

from specific incidences to more general concepts. Generalizing is essential to hypothesis formation; to be able to see things in larger perspective, to form theories and concepts, to search for basic principles. To be able to make abstract relationships in order to symbolically manipulate things.

EXEMPLIFY

To make specific, to give an example of, to concretize. Exemplify is a good way to tie down, to make real, to test a principle. It also can be used as a strategy to encourage yourself to think clearly and precisely to keep from hiding behind generalities and nebulous statements.

INCUBATE

To maintain under conditions favorable for hatching, development, or reaction; to cause to develop; to mull over; to 'sleep on'; to contemplate. Incubation has been recognized as a common phase in problem-solving, and there is evidence that strategies and plans continue to operate on the problem subconsciously during these periods, sometimes resulting in insight or sudden transformation.

PURGE

To get rid of, to eliminate, to get out of your system. Purging is the process of getting rid of immediate ideas and preconceptions by expressing them and writing them down. Purging seems to result in a definite psychic release from the strain of having to consider and remember something. You then feel free to explore other alternatives before evaluation.

HYPOTHESIZE

To propose a theory or explanation of, to develop a conceptual model, to propose a thesis, to suggest an explanation of. Hypothesizing provides a conceptual model against which to base and test future actions. It attempts to provide an explanation about how a system works before making change on the system itself.

GUESS

To act on the basis of a hunch, to make change on the basis of feeling or intuition, to take a stab. Guessing is a valuable process in problem-solving as it is a spontaneous result of all your past experiences and may well include factors that you have not consciously considered. Guesses are immediate responses to the problem and should be listened to but not accepted unconditionally.

LEAP-IN

To become involved, to throw yourself into a situation, to become immersed, to take a plunge, to jump into a problem without being totally prepared. Leaping in consciously bases you in a situation where you are going to have to react moment by moment and rely on your own resources and can greatly accelerate your progress towards the solution of a problem because it avoids potentially wasteful preparation and isolated analysis. By placing yourself in the middle of a problem, you are forced to personally experience all the factors involved and begin to get a sense of what the issues really are.

HOLD BACK

To keep from, to refrain from, to pull back for a period of time. Holding back involves detaching yourself from the immediate context of a problem and attempting to get outside of it to gain perspective; while at the same time not pulling away from the problem itself.

LIST

To place in a set order, to transform a body of information into a set of elements. Listing is the simplest strategy for recording ideas, numbers, and other items of information. Once pieces of information have been recorded in a list, they can later be recalled, organized, or evaluated. A list is the easiest form of graphic display to search (due to its linearity).

CHECK

To test or compare one set of information against another, expectations against outcomes. Checking is associated with such concepts as accuracy, consistency, performance, safety, dependability, etc. It also refers to the process of making and using check lists, reminders of operations to perform, issues to consider and spontaneous ideas to include.

MEMORIZE

To commit to memory, to structure in-

formation in the mind such that it can be easily recalled, to overlearn, to intentionally structure such that you can do something without having to think about it consciously. Memorizing allows you to carry information in your own storage system (the brain), and involves you in the information, as you have to carefully examine it in order to memorize it.

RECALL

To remember, to retrieve information from memory, to bring into consciousness past experience. Recall is the conscious use of past experience to deal with a present situation. Recall also tends to strengthen the original experience which facilitates understanding of that experience.

PLAY

To fool around with, to amuse oneself with, to change without any conscious intention, to freely explore. Playing de-emphasizes the importance of success in taking a certain action or making a certain kind of change which tends to open up the situation to chance happenings. In opening up the situation, new patterns or insights may develop which open up solutions to a particular problem.

MANIPULATE

To treat or to operate with the hands or by mechanical means, to move around, to change position, to alter relationships. Manipulation is a strategy for structuring and restructuring compositions, in order to test different kinds of spatial and functional relationships. To examine all the possibilities of structural change relating to a solution to the problem.

PLAN

To devise or project the realization or achievement of, to develop a procedure for doing something. Planning in problem-solving is the process of putting together these strategies into a program for attacking a problem. Planning involves thinking ahead, and plans may be no more than a set of intentions.

PREDICT

To declare in advance, to foretell on the basis of observation, experience, or scientific reason, to anticipate, to think in the future. Predicting is a critical strategy in evaluating the effects of an alternative and involves understanding the problem situation enough to foresee the effects of possible changes.

RECORD

To set down in writing, to register permanently, to copy in a retrievable form. Recording is the equivalent process in the external world to experiencing and memorizing in the human mind. A record is a permanent copy or image that can be recalled by searching and does not have the same limitations and susceptibility to change as information in the brain. There is theoretically no limit to the amount of information that can be recorded.

RETRIEVE

To recover, recall, locate, and reproduce information that has been previously stored. Retrieve as a strategy for pulling out past information or knowledge can present you with a rich store of material with which to work. And in dealing with a problem, strategy can help you examine where you've come from and understand where you are at the present moment.

SEARCH

To look into or over carefully or thoroughly in an effort to find or discover something, to look for, to try to locate. Searching may well be the common denominator of all strategies. Problem-solving may be defined generally as searching for a solution, and there are algorithmic, heuristic, and random methods.

SELECT

To choose, to pick, to decide, to take one. Select forces you to make a decision (arbitrary or not) and limit your actions for a period of time. Select forces you to progress into another phase of problem-solving; it allows you to go on and investigate other parts of the problem or to move toward completion of a problem.

SYSTEMIZE

To develop an organized procedure, to arrange methodologically, make into a system. A systematic strategy in problem-solving is a procedure which follows a given set of steps and can guarantee to completely search a set of alternatives if completed. It is generally algorithmic in nature, rigid, and often lengthy

to implement, but it does not involve much risk.

RANDOMIZE

To distribute as if by chance, to remove all order or structure, to act by chance, to simulate a random distribution. Randomization is a strategy to reduce systematic errors in a procedure. By purposefully randomizing your actions, you may be able to introduce the element of chance and arrive at innovative approaches (lateral thinking).

TRANSFORM

To change in composition or structure, to change in character or condition, to move from one state to another, to change the internal organizational structure of. Transformations are operations or rules governing change from one state or position into another. In this sense all strategies can be considered transformation of the problem state. Transformations can convert information into new or original forms.

TRANSLATE

To bear or change from place or condition to another, to transfer, to carry over from one medium or vocabulary to another. Translate retains the inherent structure and composition of an entity while it moves it as a whole with respect to space orientation, medium, or form of expression. Very often the solution to your problem is simply to express the same concept or idea in slightly different terms—terms that you can more easily understand.

VERBALIZE

To express in words, to describe verbally. Verbalizing is the process of explaining something in words, and in doing so it can be considered a strategy for forcing yourself to be explicit. Verbal communication is the most common medium in a highly literate society like ours.

VISUALIZE

To make visual, to see or form a mental image, to graphically describe. Visualization is a process of seeing or describing things in terms of perceptual images, and is a very powerful, dense, and often underdeveloped ability. Where physical relationships and aspects of design are to be studied or communicated, visualizing is a necessity.

WORK FORWARDS

To proceed conceptually from where you are to where you are going, from the problem to the solution, to work inductively. Working forwards seems so obvious at first that we forget that there are other basic strategies. Induction is basic to the scientific method and is required to build a logically watertight argument.

WORK BACKWARDS

To proceed conceptually from where you are going back to where you are not, to go from the solution state back to the problem state, to work deductively. Working backwards is a powerful strategy when you know roughly what the solution should be, but don't know how to get there. Working backwards can be used in conjunction with working forwards to narrow the difference between the problem state and the solution state until you can conceptually bridge the gap.

bibliography

This is a list of the most important and easily accessible books on problem-solving. Most public libraries should have the hardbound books (indicated by location and year of publication). For paperbacks, or books we suggest that any teacher actively involved in the training program purchase, we have indicated the publisher or source.

Anderson, R. C. and Ausubel, David P., editors. **Readings in the Psychology of Cognition.** New York, 1966.

A book of basic readings in cognitive psychology.

Barnes, S. J. and Harding, H. F., editors. **A Source Book for Creative Thinking.**

A basic reference to existing courses, reference sources, and problem solving experiences. It has an excellent annotated bibliography.

Borton, Terry. **Reach, Touch, and Teach.** McGraw Hill, 1969.

The best introduction to education and process. It is also a pleasure to read.

Boulding, Kenneth. **The Image.** Ann Arbor, 1961.

In this book, Boulding is exploring some of the aspects of our picture of man and the universe. He is looking at fundamental questions: how do we come to know, and how do we use our knowledge? It is one snapshot of the twentieth century mind at work.

Bruner, Jerome S. **The Process of Education.** Vintage Book. New York, 1960

In this book, Bruner relates his theories of cognitive psychology to the forms and methods of education. It is, incidentally, the book that introduced right and left handed thinking into pedagogical jargon.

Bruner, Jerome S., Goodnow, Jacqueline J., and Austin, George A. **A Study of Thinking.** New York, 1967.

A basic research text, it is a theoretical and experimental analysis of inference and thinking. It deals, in a difficult but thorough way, with one carefully worked out view of such things as conceptualizing, perception, decision making, learning, and judgment.

Covington, Martin V. 'An Experimental Program for Increasing Ingenuity in Visual Problem Solving.' U.C., Berkeley.

A program learning approach to problem solving.

Engelbart, D. C. **Augmenting Human Intellect: a Conceptual Framework.** S.R.I. Menlo Park, California, 1962.

A pioneering work on conceptual and logical tools and ways that they might be augmented or expanded through the use of technology. Someone should publish this technical report so that everyone could have access to Engelbart's fertile ideas.

Feigenbaum, E. A. and Feldman, J., editors. **Computers and Thought.** New York, 1965.

Tools for Change gained much of its insight from cognitive psychology and computer science. Highly recommended. Here you will find, for instance, the original, formal concepts of algorithm and heuristic explained and elaborated.

Gheselin, B. **The Creative Process.**

A basic, important, and insightful co-lection of essays by highly original people on how they approach and solve problems. A favorite essay is the one by the mathematician Poincare on the values of 'incubate.'

Gordon, W. J. J. **Synectics.** Harper & Row. New York, 1961.

One of the best methods for solving problems is explained and exemplified by this book.

Gordon, W. J. J. **The Metaphorical Way of Learning and Knowing.** Synectics Education Systems, 121 Brattle Street, Cambridge, Massachusetts 02138.

Buy this book. It relates the metaphorical methods of synectics to education. It is a book that grows: the purchase price includes not yet published supplements that will keep you informed.

Guilford, J. P. **The Nature of Human Intelligence.** New York, 1967.

A massive, complete, and exhaustive study of the factors of intelligence. It is academic scholarship in the best sense.

Kagan, Jerome. **Creativity and Learning.** Boston, 1967.

The papers collected in this book are designed to provoke thoughtful consideration of the larger aspects of learning. How can we teach children to think, to generate possibilities and constructive actions in the face of problems?

Koestler, Arthur. **The Act of Creation.** New York, 1964.

A free swinging, wide ranging exploration of the roots of learning, discovery, and use. Recommended as a mind stretching counterpoint to the scholarly works in cognitive psychology.

McKim, Robert. **Experiences in Visual Thinking.** Brooks/Cole, Monterey, California, 1972.

A beautiful book designed to produce new levels of awareness. It succeeds.

McPherson, J. H. **The People, the Problems, and the Problem-Solving Methods.** The Pendall Company, Midland, Michigan, 1967.

Just as it says in the title: a valuable book that categorizes and compares problem solving methods and problem solving phases.

Miller, G. A., Galanter, E., and Pribram, K. H. **Plans and the Structure of Behavior.**

An important, theoretical, pleasantly written synthesis of linguistics, cybernetics, and Stimulus-Response psychology. The resulting view has major gaps. For a balanced perspective of this whole area, it should be read in parallel with Koestler, Polanyi, and Retiman.

Neisser, Ulrich. **Cognitive Psychology.** New York, 1967.

The best introductory textbook to cognitive psychology.

Osborn, A. F. **Applied Imagination.** New York, 1963.

An easy to read, pleasant introduction to the methods of brainstorming. Many good anecdotes of the creative process at work.

Polanyi, M. **Personal Knowledge.** Harper Torchbooks.

Like the books by Koestler and Boulding, this work explores problem-solving in the deepest sense. Polanyi is especially interested in the tacit powers of the mind.

Polya, George. **How to Solve It.** Doubleday Anchor Books. New York, 1967.

The best book on problem-solving. Unfortunately, only mathematicians read it while others are unnecessarily intimidated by it. Highly recommended.

Polya, George. **Mathematics and Plausible Reasoning,** Volumes I and II. Princeton University Press, 1968.

After you've read How to Solve It, these books can result in the equivalent of a Ph.D. in creative reasoning and problem-solving. Polya develops a deep understanding of the psychology of creative thought by doing it. The reader, through experience, sees how to attack problems, what trains of thought can lead to a solution. There is much practical wisdom displayed here.

Polya, George. **Mathematical Discovery,** Volumes I and II, New York, 1965.

'Solving problems,' writes Polya, 'is a practical art, like swimming, or skiing, or playing the piano; you can learn it only by imitation and practice.' The second volume includes a comparative, cumulative index for all five of the above works.

Reitman, Walter A. **Cognition and Thought: an Information Processing Approach.**

Just to show that there is a diversity of theories of theories about how the mind works, Reitman generates another one. His allows 'the description of central processes, association structures, and complex symbolic activity.'

access library

Tools for Change has available for use by staff and trainees a functional library of materials and experiences. This library includes back-up theoretical material, specific training exercises, games and experiences, and bibliographies.

This material is available through Interaction Associates, 149 Ninth Street, San Francisco, California 94102.

future plans

Teacher training and classroom testing will be resumed on a limited scale in the Fall of 1971, and will be expanded further the following Spring. At the same time, two task forces will be developing evaluation criteria and instruments, as well as a model of the learner which will hopefully bring together Tools for Change and various schema of child development. Summer of 1972 will be taken to evaluate this work and to project the activities to be undertaken in the future.